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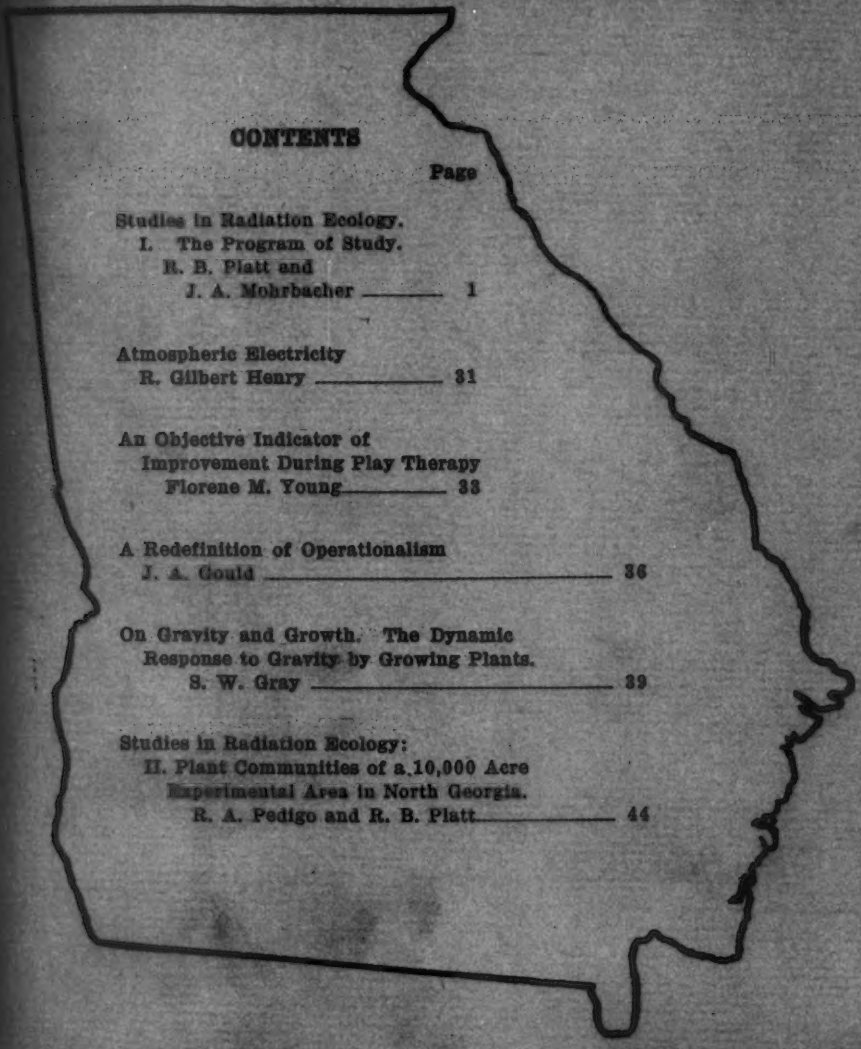

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STUDIES IN RADIATION ECOLOGY

I. THE PROGRAM OF STUDY[1]

ROBERT B. PLATT[2] and JOSEPH A. MOHRBACHER[3]

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1. INTRODUCTION

This program is an excellent example of what can result from closely coordinated and cooperative efforts between a university and an industrial organization, specifically, Emory University and Lockheed Aircraft Corporation. It is characterized by mutual advantages without accompanying disadvantages, and the program of each participant is stronger because of the support of the other. Lockheed Aircraft Corporation is concerned primarily with what is happening to the environment surrounding its newly constructed reactor facility, first in terms of possible ecological effects and second, the development of remedial and preventive measures with respect to accidents and other possible hazards. Emory University is sharing these studies and extending them into various aspects of basic research. Thus Lockheed is providing professional competence for most of the physical and chemical aspects of the broad program, including safety precaution, radiochemistry, instrumentation and transportation at the site, while Emory is providing professional competence for most of the biological aspects of the program. Both parties are sharing in the design and execution of many of the experimental procedures, while carrying out others independently of each other. The program is supported where necessary by the cooperative work of other participating organizations and institutions.

The opportunity for development of this program in its present scope was provided by the construction of an atomic reactor at Air Force Plant 67 near Dawsonville, Georgia, by Lockheed Aircraft Corporation acting as prime contractor for the U. S. Air Force. Initiative for development of this cooperative program on environmental effects came from the Atomic Energy Commission, although the Lockheed program *per se* is a part of their contract with the Air Force. A request to explore the possibilities of a joint program between Emory University and Lockheed Aircraft Corporation was received by the senior author from the Environmental Sciences Branch of the Division of Biology and Medicine of the Atomic Energy Commission. At the same time Lockheed Aircraft Corporation received by way of the Air Force a similar request. The basic lines for cooperation and responsibility for a joint program were developed in the first quarter of 1958 with Lockheed Aircraft Corporation. At the same time a research contract number AT-(40-1)-2412 was consummated by Emory with the Atomic Energy Commission for partial support of Emory University's part of the program.

From the beginning Emory's program, through its Department of Biology, was coordinated with Lockheed's through its Radiological Safety Department. This paper then is in part a resume of the present program as developed individually and cooperatively by these two groups.

A program in radiation ecology was initiated on a restricted scale by the senior author in 1956 as part of a program on the study of long range effects of radiation on natural plant populations of the granite outcrops in the Southeastern United States, the program from its beginning being supported in part by a contract with the Atomic Energy Commission. The radiation source used for these initial studies on granite outcrop plants was a General Electric OX-250 Industrial X-ray Unit with an S.R.P.-2 medical type tube having an inherent filtration of 3mm of aluminum. These studies were concentrated on the effects of radiation on basic physiological processes of selected plant populations, as well as the effects on selected communities.

In 1957, just prior to this program with Lockheed, a cobalt radiation pit was used, located at the Blandy Experimental Farm of the University of Virginia. Eighteen flats of granite outcrop communities were placed in this radiation pit at varying levels of chronic radiation over a five months period from November 1957 to May 1958. Reports on these first two years work have been made to the Environmental Sciences Branch of the Atomic Energy Commission.

Acknowledgements.

We regret that we cannot name all of those who are contributing to the planning and operation of this program. From Lockheed Aircraft Corporation, the Radiological Safety Group has, of course, a significant role, especially Robert Simpson, Kenneth Holtsinger, and Jack Selby. William E. Hardy, Chief of the Meteorological Support Group supplied information for the description of their activities, and Boone N. Bowen supplied information on the program with the U. S. Geological Survey. From Emory University, Dr. Alvin V. Beatty as Associate Investigator has contributed to the operation and organization of the program as have others of the Department of Biology. The graduate research assistants carrying out specific projects are Charles P. Daniel, J. Franklin McCormick, John T. McGinnis, and Robert A. Pedigo. Shirley Chapman has helped in preparation of the manuscripts. From the University of Georgia, Dr. Eugene P. Odum, Dr. Donald C. Scott, and Dr. Frank Golley of the Department of Biology, and Dr. Joel Giddens and Dr. Robert A. McCreery of the Department of Agronomy are generously serving as consultants. University of Georgia graduate research assistants now engaged in the program are Jay H. Schnell and William Tietjen.

2. SIGNIFICANCE

A. *Significance of Radiation Ecology as a field of research.*

The significance of such studies has been cogently expressed in the introduction to the report of an Ad Hoc Ecology Committee, convened at the request of the Atomic Energy Commission by the American Institute of Biological Sciences at the Nevada Test Site in May 1958. (Ecology Com. Rpt., 1958) The introduction follows.

"High energy radiation has been a part of natural environments of living organisms since the times of their origins. With man's use of atomic energy, background levels of such radiations have been increased measurably. Indeed, with the expanded use of nuclear devices and reactors, the carrying out of testing programs, operation of commission plants, and the possibility of radiation accidents, this increase is likely to continue at an accelerating rate. Whereas the addition to background radiation is on a worldwide scale, evidence indicates that there may be heavier concentrations of radioactivity in some areas.

Man's use of atomic energy ultimately may be limited by the effects of low level irradiation of his environment. At present, technological advances in the development of atomic power are far ahead of biological knowledge requisite to its widespread application. It is known that the evolution of plants, and animals including man, through geologic time has depended upon mutations (and their recombination) and natural selection, and that spontaneous mutation rates predictably increase with an increase in background radiation. It is not known what levels of radiation prevailed when evolutionary changes in the past occurred, nor the extent to which these changes were influenced by fluctuating radiation levels in the environments of past ages. But it is at present generally believed that there is no threshold for such radiation effects and that any increase in radiation may result in changes in the gene and chromosome structure of any organism, and hence, in its life process and those of its descendants.

It is not known whether small increases in radiation background will have pronounced or even measurable effects on biotic communities in natural environments, but neither is there assurance that they can not have a significant influence. Other catastrophic events have followed relatively minor environmental changes, e. g. Pleistocene continental glaciations which appear to have resulted from initial small changes in temperature.

It is unfortunate that long term (15- , 20- or even 50-year) ecological studies were not initiated before there was any artificial contamination of natural environments. Already there have been many occasions to regret this lack of ecological information, e. g., a more productive approach to the problems involved in the biological effects of fallout which such data could have afforded from the onset of fallout.

It is urgent that broad studies be commenced on the effects of chronic exposure to ionizing radiation upon communities of plants

and animals in their natural environments. Such studies should be established at the earliest opportunity."

B. Significance of this program.

From its beginning, the opportunities for development of this cooperative program have been regarded as unique in the field of radiation ecology. The elements which make it unique are as follows: (1) The reactor, of ten megawatt power, is to be only partially shielded, thus creating a gamma and neutron radiation field in the midst of a natural area which possesses a variety of habitats. (2) Preliminary studies of the area could be made prior to the release of radiation from the reactor, Lockheed beginning its studies of geology, topography, surface water, background radiation, and microenvironment from one to three years prior to the operation of the reactor, and Emory instituting its studies on soils and on plants and animals approximately a year prior to reactor operation. Thus background activity, vegetation maps, reference collections of plants and animals, topographic, geological and soil maps and the development of basic programs of research are all completed, or essentially so, prior to reactor operation. (3) Through the work of the Georgia Department of Public Health, the U. S. Geological Survey, Lockheed microenvironmental and radiochemistry programs, the contributing programs from the University of Georgia on animals including mammals and aquatic invertebrates, and on soil physics, soil chemistry, and soil microorganisms, and those of Emory University on plants, including forest communities, forest floors, old fields, and energy relationships, a comprehensive and integrated program of ecological studies is provided, based on radiation as being a significant element in the environment.

C. *Educational Significance.*

The basic decision was reached in the formative stages of this program to develop the academic aspects of a joint program between faculty members and their graduate students, thus providing a broad training program in radiation ecology on both the masters and the doctoral levels. It is in this way that the programs of both Emory University and the University of Georgia are being carried out. Principal elements are (1) that the major investigations will be carried out by graduate students, under the direction of their advisor, and also under the general supervision of the academic consultants, and the professional personnel from Lockheed, (2) the taking of supporting courses in radiation biology and radiation physics, and (3) the development of economic and practical aspects of radiation through contacts provided by an industrial organization through its operation of an atomic reactor.

3. OBJECTIVES

The broad objectives only are presented at this point. Their many subdivisions will become evident throughout the rest of this paper. Whereas the first three objectives are of primary concern to Lockheed, the fourth objective is the one of primary concern to Emory University. There is a two-fold relationship between objectives, one being concerned with the direct effect of neutron and gamma radiation on the natural environment, and the other relating to the effects resulting from the transfer and accumulation of secondary radioactivity.

The objectives are:

(1) To determine what increases in radioactivity in the environment can be attributed to reactor operations, and what can be attributed to other sources such as fallout.

(2) To establish permissible doses of radiation in nature in terms of the ultimate effects on mankind, and also to establish bases for the intelligent use of emergency measures in case of radiation disaster, especially in limited areas.

(3) To develop a general body of knowledge and philosophy useful in the evaluation of other pressing problems of the atomic age, such as low food waste disposal, and environmental monitoring programs which are associated with widespread military and civilian uses of radiation sources.

(4) To study the ecological effects in a very broad sense, of continuous and discontinuous gradients of neutron and gamma radiation on selected natural environments over short and long periods of time under natural and controlled conditions. This involves two fundamental approaches to radiation ecology, the first being the effects on individual species in terms of their ecological, genetical, physiological, morphological and other inter and intra specific characteristics as evident throughout their life cycle and under the varying conditions in which they exist. The second is concerned with ecological effects on communities of organisms, especially on those characteristics which are unique to the community rather than to the individuals of which the community is composed. In another sense, the study will attempt to include basic aspects of the whole spectrum of edaphic, climatic, and biotic investigations.

4. PROJECTS WHICH PROVIDE SUPPORT FOR THIS PROGRAM

These projects vary widely in their administrative relationships to this program. Some are carried out by independent agencies, such as the Georgia Department of Public Health, whose program is based on their own responsibilities for radiological health protection. Yet their program, which assumes responsibility for surveillance of radioactivity off the 10,000 acre reservation, is as fundamental as those studies which do the same on the reservation, and the relation-

ships are characterized by a mutual sense of cooperation and responsibility.

Other supporting projects have been designed specifically to complete gaps in the total program, such as the one on a plant community survey of the area. This is a necessary complement to the directly comparable surveys on geology, soils, microclimates, topography, radioactivity, etc., especially in that this represents the only biological survey of those completed.

A. *The off-site environmental monitoring and study program of the Georgia Department of Public Health.*

The Georgia Department of Public Health is charged with the basic responsibility for the maintenance of the health of the people of this state, and since 1943 the Department has been active in the field of radiological health protection. This past experience has enabled the Department to inaugurate an environmental monitoring program at the Dawsonville site. This program encompasses the surveillance of radioactivity levels in water, air, soil, vegetation, and other biota in the areas outside the site proper.

A bill of the 1957 legislature of this state created the Georgia Water Quality Control Act. A section of this act states that it shall be unlawful to disseminate toxic or radioactive substances into the waters of this state to the extent that they would adversely affect the health of the people of this state. In an effort to evaluate the liquid radioactive waste disposal from the Dawsonville site, a system of water monitoring stations has been established down streams at Rome, Cartersville, and Canton on the Etowah River. Three additional stations have been established on the drainage waters before they enter the site proper, and three stations immediately after the waters leave the site. These stations have been in operation several months and data has been accumulated on the radioactivity levels before the company begins operations.

For the past three years, the Health Department has participated in the National Radiation Surveillance Network Program. An air sample has been operated twenty-four hours per day, seven days a week. This has enabled the Department to keep up with the daily variations in radiation levels in the air. This data is necessary in evaluating properly the effect of fallout on water, soil vegetation, and other sampling media. In addition, a system of film badge monitoring stations is being established for monitoring radiation levels in air up to approximately two miles distant from the site boundary fences.

Complementing the above outlined program will be a network of soil and vegetation sampling stations, that will enable the Department to evaluate the long term deposition and uptake of particulate activity emanating from the Dawsonville operations.

B. *The United States Geological Survey program on geology and hydrology.*

In 1956, the United States Geological Survey began an investigation into the geologic and hydrologic properties at the site of Air Force Plant 67. The purpose of this study was to determine the effect of hydrolic and geologic features at the site of Air Force Plant 67 on the feasibility and safety of ground infiltration disposal of radioactive wastes, building construction, and reactor design.

The topography of the site is one of much dissection and steep slopes. Streams have firmly entrenched meanders. Maximum relief is about 400 feet. The area is in the Piedmont Province southeast of the Appalachian Chain.

The geology and structure of the site was obtained by field mapping. It is a highly metamorphosed area, with schists, gneisses, amphibolites, and other metamorphic rocks. Some igneous intrusion is evidenced by the presence of migmatites, quartz veins, and pegmatites. Joint systems are generally well developed, but faulting, except for relatively minor shear zones, are not readily detectable. The rocks strike toward the northeast and dip to the southeast at angles ranging from about 30° to vertical.

Samples have been collected for ion exchange capacity and grain size analysis. These factors influence the efficiency of radioactive waste fixation. Ion exchange capacity is relatively low, averaging about 5 milli-equivalents per 100 grams. The grain size of soil samples runs from about 30 to 50 percent sand and gravel size, 25 to 30 percent silt size, and 25 to 40 percent clay size.

Several phases exist in the study of the hydrologic properties of the site. Samples were collected for water quality determinations, and these show the ground and surface waters to be mostly very low in dissolved solids. However, the concentration of iron is in places relatively high.

An inventory of existing wells on and around the site was made. In addition, 26 test wells and 107 auger holes were drilled primarily at seepage pit locations. These have been used in tests to give data on the water bearing characteristics of the aquifers intersected, and in the future they will serve as monitoring stations to ascertain the movement of radioactive wastes. Pumping and bailer tests of these wells with other data indicate a maximum movement of the ground water of about one foot per day. As hydraulic gradients increase with the addition of large volumes of liquid, this rate will increase. At one foot per day about three years will elapse before liquid wastes reach the Etowah River, provided early release is not effected by springs.

Water level measurements have been made on existing and drilled wells and auger holes over a period of two years. Continuous recorders have been used on some wells and periodic tape measurements made on the remainder. These data will enable the prevention of an undue amount of ground water mound build-up. Preliminary infiltration tests were conducted on the seepage pits. These were made by using

18 and 24 inch infiltrometer rings. An indicated 4 to 7 gallons per minute with an approximate one foot head would be accepted by the pits.

Plans for the future include the continuation of collecting water level data, especially in the vicinity of seepage pits. This will be checked carefully to avoid overly steepened gradients on the formation of new springs.

Seepage pits will be more thoroughly tested to provide infiltration rates and direction and speed of ground water movements. Suitable tracer material will be used to provide the latter information.

C. *Micrometeorological activities of the Meterological Support Group of Georgia Nuclear Laboratories.*

During site selection activities for locating the Laboratory, climatology studies were made of the area using high correlation offsite data from nearby United States Weather Bureau cooperative stations, city and military observatories.

In June, 1956, a meterologist was assigned to the site and appropriate observatories were established to observe and record on continuous strip charts the wind direction and speed, temperature, relative humidity and precipitation. The primary observatories were located in the valley adjacent to the Radiation Effects Reactor site, on Hill No. 1311, at a point 5,000 feet south of this site and at the Nuclear Support Facilities area.

Data from these stations from time of establishment to present were tabulated hourly and machine assessed using the I.B.M. 704 electronic computer.

Observatories were also set up and operated at various other sites principally in the Etowah River valley above and below the reactor site and at several locations in the hills to the north. All observed data were tabulated and all strip charts are on file.

In September, 1957 a 150 foot meterological tower was constructed adjacent to the Nuclear Support Facility area and equipped with multiple wind and differential temperature instrumentation. A weather radar was also installed at this time to aid in the location and tracking of potential tornado situations.

The most recent instrumentation now in process of being installed includes a 320 foot steel weather tower in the Radiation Effects Facility valley equipped with 3 wind and 5 differential temperature stations the data to be telemetered to the Weather Station in the Nuclear Support Facility.

Weather teletype Service 'C'' data are used to plot both surface and upper air weather maps and charts, and vertical soundings for forecasting purposes. The Air Force weather facsimile service is being installed to replace this service which will thus become supplementary.

Since completion of the reactor safeguards reports, temperature gradient and wind data along with current synoptic data have been used to develop a technique for forecasting the vertical tempera-

ture gradient at the Radiation Effects Facility location. This is essentially a forecast of good or poor diffusion conditions up to a point of 310 feet above the valley floor and is made daily and transmitted to the reactor operations officials 24 hours in advance.

Daily climatological data are also provided the United States Weather Bureau for publication in the form of a monthly summary for the site.

D. *Major plant communities of the 10,000 acre experimental area.*

The major plant communities of the 10,000 acre experimental area have been described by Pedigo and Platt (1959). The objectives of this study were first to identify and map the distribution of the several plant communities over the 10,000 acre reservation, and secondly, to obtain data on the composition of their overstories. The significance of the study is three fold. (1) It characterizes and describes the vegetation of the area in a way that will be useful in planning and evaluating the other studies being carried out in the area. (2) By describing the vegetation as it now exists by methods which may be repeated, changes occurring in the next ten, twenty, or thirty years may be defined. This may be of extreme importance in terms of the diversity of studies projected. (3) This study constitutes a vital unit in the series of maps and surveys being made for the area. The ultimate objective of the whole program of studies is to determine the biological effects of radiation, and this is the only survey being made which is biological.

This area, like similar ones throughout the Piedmont, has a long history of continued disturbance by white inhabitants since about the middle of the last century. This has been primarily by clearing for cultivation, or by lumbering. Farming was active until the end of the last century when wholesale abandonment of farms occurred. Consequently these areas have gone through relatively advanced stages of secondary succession. However, disturbance by fires either from Indian activity or by natural causes, has at all times probably played an important role in the vegetation of the area.

The major plant communities were mapped using aerial photographs, contour maps, and field observations. Four major plant communities were identified, oak-hickory-pine, disturbed areas, pine, and flood plain. After these were mapped, the overstories of those with tree dominants were sampled using the quadrant method adapted to this purpose by Cottam and Curtis.

Oak-hickory-pine is the upland climax community, occupying about 80 percent of the area. The composition of this community is influenced by topography, ranging from a situation of mixed oak with less than ten percent pine and hickory on the north slope, to a combination in which hickory and pine represent almost half of the trees on the south slope. Some of the species of oak also show correlation with the topography, notably scarlet oak and chestnut oak on the north slopes and in the valleys, and southern red oak on the hill tops and south slopes. In the natural state it is probable that pine

plays a more important role than is evident from the sampling, since a great deal of pine has been selectively removed from this type of community on the hill tops and flat areas.

Pine stands are pure short leaf pine or loblolly pine with only a small amount of mixing. Short leaf pine is probably the native pine in the area, loblolly pine being either planted or dependent upon cultivated fields for establishment. The disturbed areas, being created by extensive lumbering or clearing, are developing into climax communities. These occupy less than 10 percent of the area. The flood plain communities occupy a narrow band along the streams, and are heavily dominated by river birch. Of special interest is the fact that hemlock and white pine, which occur sparingly in the area, are at the southern limits of their distribution.

The findings of this study are in general agreement with the few studies conducted elsewhere on the Piedmont Plateau. This is the first such study made in the southernmost part of the Plateau.

E. *Biological inventories of the experimental area.*

One of the first activities initiated by Emory University was the development of a biological inventory of the experimental areas. The value of such an inventory is incalculable in that it contributes directly and indirectly to the intelligent planning, execution, and interpretation of the many specific projects which make up the primary part of the program. These inventories will be properly identified, mounted or preserved, and housed collections made of various groups. Collections which are already in advanced stages of completion are of (1) the vascular flora, (2) mammals, (3) birds, and (4) aquatic invertebrates. Others projected are (1) cryptogamic flora, (2) soil micro-organisms, and (3) fish and reptiles. Additional collections will be planned as opportunities permit. Emory University and the University of Georgia are carrying out these studies.

F. *Aerial photography.*

Aerial photography is being used (1) as a base for the preparation of maps and overlays of many other correlatable factors, such as radioactivity, soil, and vegetation, and (2) for interpretation of changes in the area brought about by radiation or by natural causes such as succession.

Because of the size of the radiation field, aerial photography will perhaps be the best single indicator of pronounced changes in the environment. By comparative use of the control area two miles northeast of the radiation field, photographs taken of each at intervals throughout the year over several years time should yield extremely valuable data which could not be obtained in any other fashion. In order to further enhance the value of such studies, color, infrared, and black and white are all being used. Because of the use of infrared in aerial photography for camouflage and for forestry practices, this may prove to be an interesting tool in the determination of radioactivity effects from the air. Several sets of photographs

are already available of the 10,000 acre (16 square mile) site, and of the 400 square mile area surrounding it.

5. EXPERIMENTAL AREAS

A. *10,000 acre reservation of Air Force Plant 67.*

The reservation of Air Force Plant 67 is an approximately square and heavily wooded area of 10,000 acres or 16 square miles. (Figures 1 and 2). It is located in Dawson County, Georgia, about fifty miles

FIGURE 1. *Topographic map of the 10,000 acre reservation of Air Force Plant 67, operated by Lockheed Aircraft Corporation. A is the control area, B the radiation field inside the 3600 foot perimeter fence, with the reactor in the center, C the gamma field around the railroad siding, and D is the administrative and laboratory area. The scale is 1000 feet per grid.*

north of Atlanta on the upper Piedmont Plateau. It has always been sparsely populated, lumbering and fire being the primary causes of disturbance. The entire area is surrounded by barbed wire fence inside of which is a fire break forty feet wide. A marked topography map of the area is presented. (Figure 1).

The climate of the area is temperate and continental, the mean annual temperature being approximately 60°F. with short cool winters and warm summers. Extreme temperatures of 100°F. and 0°F. occur only in occasional years. The average rainfall is 50 to 60 inches, the heaviest rains occurring in winter and spring, but rainfall being fairly well distributed during the year.

The area has a rolling well dissected topography, in which the underlying granite gneiss and schist have been pushed up into a series of ridges extending in a northeast southwest direction with a total relief of about 400 feet. The soils are characteristically residual, only a small portion being alluvial. The entire reservation is

FIGURE 2. *Panoramic aerial view of the central part of Air Force Plant 67, the reactor and radiation field being in the center.*

drained by the Etowah River which rises in the Blue Ridge and enters the Alabama-Coosa system at Rome, Georgia. The Etowah and its tributaries are actively downcutting throughout the area, even though they are bordered in some areas by narrow strips of

FIGURE 3. *Aerial views of the reactor site. In the lower view, the reactor is in the aluminum building at the intersection of the three railroad spurs, the control rooms are underground and to the right, the 500 foot entrance tunnel extends to the right. A row of experimental plots show in the bottom. Most of the experimental plots are along radii rather than arcs.*

flood plain. Shoal Creek and the Amicolola River are the principal tributaries of the Etowah within the reservation.

Oak-hickory-pine is the upland climax community occupying about 80 per cent of the area, with much smaller areas occupied by pine, by disturbed and cut over areas, and by narrow flood plains along the stream.

B. *Radiation field around the reactor.*

The radiation field is illustrated in figure 3. The source of radiation was designed and constructed primarily to study the effects of high level fast neutron and gamma fluxes on aircraft systems operat-

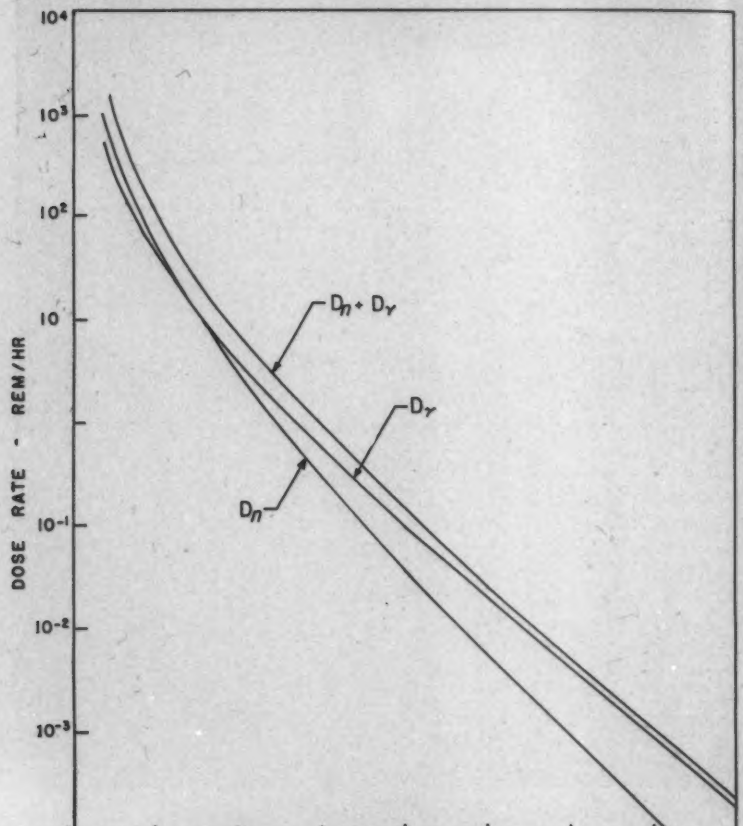

FIGURE 4. *Calculated dose rate versus distance curves for the Radiation Effects Reactor at ten megawatts unshielded.*

ing in environments simulating those expected in a nuclear powered aircraft. In order that these objectives could be accomplished, a large radiation volume is required. This gave rise to the present design in which a 10 megawatt thermal reactor is operated above ground with only partial shielding, thus subjecting the environment to relatively high radiation exposures.

The Radiation Effects Reactor is a modified swimming pool type reactor using MTR fuel elements with flat plates. The fuel is highly enriched in U235. The reactor is forced water cooled and water moderated. The reactor core is enclosed with a ½ inch thick stainless steel pressure vessel. Shielding consists of the six inch water moderator, a ½ inch boral thermal neutron shield, and a 12 inch water shield tank composed of compartments. The compartments can be drained or filled with water to vary the radiation spectrum.

The design operating schedule calls for operations every other week. The cycle is six hours, to permit changing of operating crews, and back to full power. This cycle will be repeated until a total of 100 hours of irradiation time is reached.

Calculated neutron and gamma dose rates versus distance from the reactor operating at full power are shown in figure 4. An RBE of 10 was assumed for the calculation of neutron exposures. It should be noted that the thermal neutrons are effectively shielded out at the reactor by the boral. This greatly reduces the activation of building materials and the soil by thermal neutrons. The activation of the soil by thermalization of fast neutrons is expected to be slight and for the most part only short lived radioisotopes will be produced. In addition, the major action will be at a depth of no less than six inches below the soil surface. This reduces the problem of possible wash off of the activation products by surface drainage.

From data available, it is apparent that a large radiation field will be produced which permits the study of effects of radiation fluxes ranging from relatively high to essentially background levels. It is not expected that these high radiation fluxes will denude large areas of all vegetation, only those close to the reactor. Many plants can tolerate daily exposures, in the order of 1000 to 6000 r per day without apparent damage. Denuded areas will be treated with soil binders or asphalted to prevent the possible transfer of radioactive contamination.

The entire reactor facility is enclosed at a radius of 3600 feet by an eight foot chain link fence topped with three strands of barbed wire. The fence is designed and constructed to retard wild life from entering or leaving the area. The fence, roving patrols, and other safety controls, are expected to prevent inadvertent and/or illegal entry to the area.

C. *Gamma field at the railroad siding.*

After exposure to direct radiation from the reactor, the units being tested by Lockheed are to be parked on a railroad siding between the reactor and the laboratories, so as to lose much of their radioactivity. Thus the area surrounding this siding will be subjected

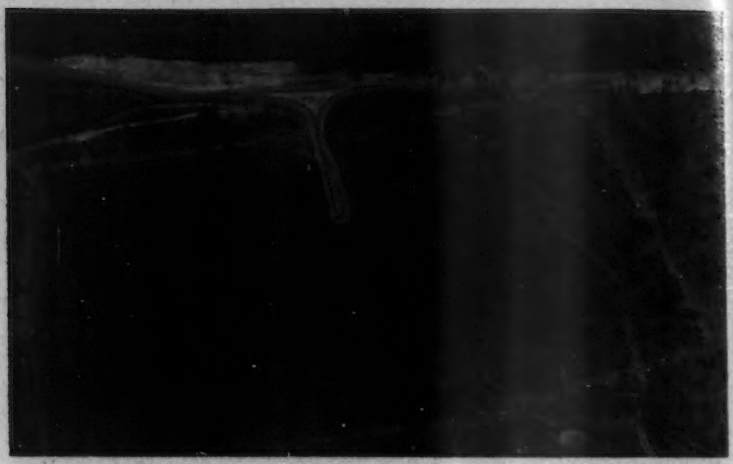

FIGURE 5. *The gamma field at the railroad siding, enclosed by a chain link fence. The siding is in a ravine of about 100 feet total relief.*

to periodic exposures of relatively high radiation only. The siding is in a small naturally wooded ravine. The area is enclosed by an eight foot chain link fence topped with barbed wire. (Figure 5).

D. *Control area at the 10,000 acre reservation.*

A control area which is very similar to that of the experimental area around the reactor has been established some two miles northeast of the reactor site, (Figure 6). This area has been chosen after a careful survey of the entire 10,000 acre reservation. It consists of a flood plain, comparable to that at the radiation field, located along the Amicolola Creek, with flood plain forest along its bank, and oak-hickory-pine, and disturbed community types extending on the slopes above it, and having the same substrates, and soils, and the same slopes and aspects as those of the experimental area. Duplicate plots are being set up in this control area for all of those set up in the experimental area.

E. *Cobalt 60 radiation field on the Emory campus.*

Because of the intermittent nature of the reactor operation, controlled doses of radiation cannot be obtained at the experimental area around the reactor. Because of the inherent value in such controls, a cobalt 60 radiation field has been constructed on the Emory campus to provide such a facility, (Figure 7). This field is fifty feet in diameter, with a 160 curie Cobalt 60 source located in the center. The field is surrounded by earthen bunkers twelve to fifteen feet high, and the entire area is surrounded by an eight foot chain link fence. Skyshine is prevented by a two foot thick concrete shield placed above the source. The source may be raised or lowered by

FIGURE 6. *The control field looking southeast. The Amicolola Creek is on the left of the old field on the flood plain. The white squares are quadrats for succession studies.*

FIGURE 7. *Cobalt 60 radiation field on Emory University campus. The source will normally be under the sky shield in the center of the fifty foot diameter area, but prior to entry it will be lowered five feet below the ground surface from the control house by the entrance drive.*

means of an electromagnet operated by a hand wench in a control house outside the radiation pit. A detailed series of safety controls have been installed to protect (a) those working in the field, (b) personnel outside of the area, and (c) those gaining illegal entry.

Experimental plots have been established in the shape of spokes from the center of the field toward the periphery, thus providing for radiation gradients along the spokes. Each plot is forty inches wide and eighteen feet long, thus permitting the establishment of strip quadrats down the center, with widths varying from several centimeters up to a meter. The natural environments under study will be duplicated in as far as possible in these experimental plots. For example, the plots for old fields are eighteen inches deep, thus permitting the introduction of the A and a major portion of the B horizons, these being established in as undisturbed a condition as possible. Comparable setups are being provided for other natural environments, such as forest floors and granite outcrop communities.

The radiation gradients can be controlled by varying thicknesses of lead, either interposed as sheets at various points along the strip quadrat, or located against the cobalt source. The dose rates may vary from a maximum of 200 r per hour at a distance of four feet from the source on down to as low an intensity as one would desire. Control plots can be established by blocking out the radiation along given spokes.

F. *Granite outcrops in the Atlanta area.*

These granite outcrops have been used as experimental areas for approximately three years. Because of the unique nature of the plant communities which occur on them, and the basic studies already completed, they will continue to serve as basic experimental areas for Emory University. The unique characteristics of these areas are ultimately derived from the unusual formation and arrangement of the outcrops. They occur as large areas of exposed granite, varying from less than one to thirty or forty acres in extent. On these outcrops, small weather depressions are found one to several inches in depth with flat bottoms. As they are being formed they fill up with soil, and islands of vegetation composed either of single species or of relatively simple communities are developed on them. Since they are formed on granite, they are ecologic systems closed at the bottom, without the usual soil percolation below. The communities, only a few feet across, are small enough that representative portions may be brought intact into the laboratory for controlled studies. Furthermore, the communities on these outcrops are relatively stable over several years time, succession occurring at a much lower rate than that found, for example, in old field succession. Most of the plants in these communities are annuals, thus assuring a complete generation each year. This greatly facilitates the study of the effects of radiation on genetical factors, and also the effects of radiation on all stages of life cycles within a few months time.

6. PROJECTS ON BACKGROUND RADIOACTIVITY AND RADIATION DOSAGE.

A. *Environmental sampling program for the determination of background radioactivity.*

The development of a comprehensive sampling program for determination of background and induced radioactivity has been given particular attention, inasmuch as it is fundamental to the other phases of the program. The fundamentals of this, which are given here, were developed jointly by Emory and Lockheed.

The objectives were (1) to determine natural or background radiation levels, (2) to determine the production, distribution, and biological accumulation in nature of radioactivity induced by the neutron field, (3) to determine the distribution and biological accumulation of isotopes from waste disposal seepage basins, and (4) to distinguish between increases in radioactivity in the environment produced by fallout from that produced by the reactor operation.

The basic considerations are two-fold: first that samples should be ecologically, taxonomically, and physiologically comparable in space and time, in as far as conditions will permit, and secondly that samples may vary according to (1) micrometeorological conditions, especially during time of fallout, (2) topography and its effects on micrometeorological conditions, (3) nature of substrate: soil horizons and soil types, (4) solubility of the isotopes, (5) nature of receptors, including size, shape, position, exposure, and texture, especially for leaves, (6) age of receptor (as for example leaves), i. e., time available for receiving fallout, (7) physiological nature of species, i. e., differential uptake, and (8) position of groups with respect to strata carrying radioactive water, and the distribution of physiological uptake to the leaves (i. e., one part of a tree could be radioactive and another not).

B. *Aerial survey of background activity.*

The 10,000 acre reservation and environs for several miles around were mapped the first week in December 1958, as a part of a special project on a nationwide aerial survey of background radioactivity being carried out by the Atomic Energy Commission. The survey was made with a specially equipped plane, operated by the U. S. Geological Survey. An interesting part of this particular survey is that when the results are available, they can be correlated with (1) vegetation, (2) soils, (3) rock substrate, (4) topography, and (5) micreoenvironment of the area. This survey was made prior to any radiation being released into the environment by the reactor operation.

C. *Analyses of background radioactivity by Lockheed.*

Gamma spectral analyses will be performed on representative samples of vegetation, water, air, and soils prior to reactor operations. This will provide an effective method to identify certain

naturally occurring radioisotopes of interest. These studies will continue after reactor operation begins to determine those radioisotopes introduced by reactor operations. As backup to the spectral analyses, radiochemical analysis will be made to determine the presence of specific isotopes such as Sr^{90}.

FIGURE 8. *Representative habitats in the 10,000 acre reservation. The upper two are oak-hickory-pine communities. The middle left is upland cut over area and the middle right the old field at the reactor site. The lower left shows the flood plain community along the Etowah River at the reactor site, and the lower right one of the few pine stands in the area.*

D. *Determination of the gamma and neutron radiation fields.*

The initial criticality of the R.E.R. is expected in mid-December. This operation will be conducted with the reactor submerged in the reactor storage pool. It is not expected that radiation fields will be detectable at the water surface. Operation of the reactor out of the pool is not expected to begin until early January 1959. Initial reactor operations at the above ground operating position will be conducted solely for the purpose of determining gamma and neutron distributions at varying distances for different shielding configurations. Continuous radiation monitors, located throughout the field, will provide the primary method of determining radiation exposure at any point on the reservation. This data will be continuously recorded. To augment this monitoring system, to more accurately determine radiation fields at specific locations, and to provide additional information for the determination of the radiation exposure in any area, total dose monitors will be installed. These monitors will be composed of activation foils, gamma and neutron film badges, gamma dosimeters, and low level beta chambers. This method of monitoring has been chosen to provide economically the necessary information within reasonable limits of accuracy as required by the overall program.

E. *Projected ecological analyses of radiation damage.*

A realistic concept of the probable ecological effects of the anticipated dose rates is essential to the establishment of study areas within the radiation field. Accordingly, a master graph was prepared which showed on the horizontal axis distance from the reactor superimposed upon the topography for given azimuths. On the vertical axis was shown the accumulated doses of gamma and neutron radiation for 100 hours, one month, three months, six months and one year periods, based on the operating schedule as given in the above section on description of the radiation field.

The median lethal dose for small mammals was estimated at 200 - 800 r, and for most plants, 10,000 - 40,000 r. By comparing total expected dose with these figures, and then applying moderating factors of topography, environment, and behavior, the lethal effects may be estimated. While this does not indicate at all any significant devastation, it does give promise of creating excellent experimental conditions. Since the maximum dose rates are subject to reduction pending the reactor operations schedule, the locations of study plots have been made as elastic as possible, and in most cases laid out along radii of decreasing intensity.

Since the neutron field does not extend beyond 1000 feet, this zone of accumulation and transfer of radioactive material is surrounded by a buffer zone of about 2600 feet, ending at the 3600 foot perimeter fence. In order to arrive at an understanding of the significance of this buffer zone, a list was compiled of all mammals expected to be in the area. The home range was determined, their probable food chains, and finally their skull size, in terms of passing

through the 1½ inch openings of the chain link fence. Also their probable tendency to climb over or dig under this fence was set down. The results indicate that few animals are of probable importance in this regard, those of most concern being the bob cat, fox, rabbit, weasel, otter, and mink.

7. PROJECTS ON PRODUCTION, TRANSFER, AND ACCUMULATION OF ISOTOPES WITH REFERENCE TO THE NEUTRON FIELD

The primary considerations of the background monitoring program are to determine the natural levels of radiation prior to operations and to maintain a check on the increase, if any, of the levels. It will then be possible to determine possible trouble areas and to initiate preventive solutions before serious problems in radiation controls can arise. The philosophy adopted is to investigate within reason all areas where potential problems may arise. The following projects are involved under present planning: (1) Determination of radioactive isotopes expected to be produced in this environment by the neutron field, (2) Evaluation of potential biological significance of those with reference to their half life, solubility, and physiological uptake and concentration by both plants and animals, and (3) Selection and study of potential biological accumulators of radioactive isotopes. Special studies include:

Soils. Blocks of soil will be selected along radiation gradients from the reactor to serve as yardsticks or base lines for distribution within the soil profile. These soils have been analyzed to determine the percentage of isotopic composition for the prediction of neutron induced activity.

Soil organisms. Efforts will be made to determine initial retention of isotopes by soil organisms.

Land plants. Herbaceous plants are the most probable accumulators, and both experimental and native plants will be monitored.

Land animals. In natural food chains, the herbivorous animals, both veretebrates and invertebrates, are the next links. Invertebrates, especially grasshoppers, etc., will be continuously monitored following radiation exposure. Vertebrates feeding directly or indirectly on plants will be monitored if the examination on previous food links are positive.

Aquatic plants and animals. Since rain water may wash the isotopes into the Etowah River, a series of sampling stations will be established along the river, both above and below the site, where screening of potential accumulators will be systematically carried out. The most probable accumulators are the fresh water clams, caddis fly larvae, and algae.

In the section below, projects in soil chemistry, soil physics, and soil microorganisms are closely correlated with these studies, as are also the ones on secondary succession and on forest floors.

8. PROJECTS ON LONG RANGE EFFECTS OF RADIATION ON SELECTED ENVIRONMENTS

The projects which make up the basic academic aspects of the broad program as developed primarily by Emory University and the University of Georgia, are grouped in this section of the paper. The point of view in all of these studies is not only to ask what is happening to these natural environments, in terms of radiation effects, but also to ask why and how, in terms of whole organism response. The ultimate contribution rests on the fact that the approach is ecological and the units of study are natural populations and communities. These projects have been selected in order to provide a balanced program between plants, animals, and microorganisms, or in another sense for the biota, both above and below the ground surface, or in still another sense, a balance between community types, and their primary biological functions.

A. *A study of secondary succession in fields radiated with gamma and neutron radiation.*

A study of secondary succession in newly abandoned fields, subjected to both gamma and fast neutron radiation, is being conducted by Emory University. Permanent quadrats have been established. One series begins at 60 feet from the source and extends on a radius through a distance of 2400 feet, while the second series is located on an arc at a distance of 600 feet from the reactor source. These quadrats are in pairs, one being in its condition of natural development since abandonment of the field in 1956, whereas the other of the pair is a freshly dug bare quadrat from which all vegetation, including roots, has been removed. Similar quadrats are established in the control field.

This will make it possible to observe the effects of radiation not only on succession at a three year old stage, but also at its beginning stage. The dominant species in this succession, *Erigeron canadensis, Aster pilosus, Andropogon virginicus,* and *Diodia teres* are to be studied by ecological methods. Studies in the green house, correlated with those in the field, will be included with emphasis on the extremes of the microenvironment. The plants will be studied from seed germination through seed dispersal. A special series of studies will be made with regard to total energy balance using photosynthesis-respiration and productivity techniques or some combination of the two.

As an additional control from gamma radiation, three experimental plots are to be set up in the cobalt radiation field on the Emory campus, each of these to represent a different stage in succession.

B. *Effects of chronic gamma radiation on a forest floor.*

A study on the effects of radiation on a forest floor is being carried out by Emory University. This rather extensive field problem concerns radiation effects on the chemical and physical properties

of the soil, leaf litter, roots, stems, and leaves within relatively mature stands of oak-hickory, with special reference to their effects on the ecology of the forest floor. Three research areas have been selected ranging from 1000 to 3000 feet from the reactor. The stand closest to the reactor should receive approximately 7500 roentgens of gamma radiation per 100 hours of reactor operation at maximum power, while the stand farthest away should receive less than 75 roentgens over a comparable period of time. Such a diversity of dose rates should have readily observable differential effects upon natural forest stands. The plots in the control area have been selected to be as nearly as possible like the experimental stand with reference both to the forest cover, microclimate, and soil. In addition, an experimental forest floor will be established in the cobalt radiation field on the Emory campus for checks and for control studies of radiation in certain aspects of the investigation.

By making periodic field and laboratory observations and analyses on the chemical and physical properties, it is hoped that valuable information will be obtained about the total nutrient cycle in the plant and soil complex plus the excellent opportunity for description and conclusive basic information about radiation effects on the growth and maintenance economy of naturally occurring forests. This study will be carefully coordinated with the work on soils to be carried out by the Department of Agronomy of the University of Georgia. One of the more interesting aspects of this study will be the effects of the forest stand on the distribution of radiation through the stand.

C. *Ecological effects of gamma and neutron radiation on physiological responses of populations and communities.*

The ecological effects of radiation on basic plant physiological processes, with special reference to photosynthesis-respiration rates, has been initiated by Emory University. One of the basic objectives in carrying out this program is to develop ecological-physiological yardsticks against which radiation damage can be evaluated for populations and communities. At the present time studies on the effects of radiation of natural plant and animal populations are hindered by the lack of such yardsticks, most of the accumulated data at the present pertaining primarily to laboratory animals or economically important plants or a few selected experimental organisms. Furthermore this data often applies to only one phase in the life cycle of the plant or animal in question rather than to each of its species.

Experiments will be designed to analyze carefully selected experimental plants in the following situations: (1) their natural environment, (2) their environment plus radiation of varying intensities, (3) in a semi-controlled environment in the green house, and (4) in the cobalt radiation field on the Emory campus. Determinations will be made on photosynthesis-respiration rates by means of a portable infrared gas analyzer (Beckman Model 29). With this

instrument it is possible to make accurate measurements on a single leaf over a very short period of time, or of a small community. In as far as possible, these will be coordinated with other aspects of the total program.

D. *Survey of the major macroscopic invertebrates of the Etowah River.*

A study of the macroscopic invertebrates of the Etowah River is being made by the University of Georgia. The primary objective is to determine the distribution and abundance of the major macroscopic invertebrates and to attempt to develop some of their ecological relationships. The methods used involve periodic sampling in various habitats. Sand and silt samples are taken with the Dendy inverting sampler. Collections of organisms around rocks and shoals and those inhabiting communities of *Podostemum sp.*, both on sand and rock, are made with the Surber sampler. Surface organisms are being collected when seen. Brush boxes have been placed in the stream, and when partly filled with silt, provide a sampling technique of silt and inhabitants. Several major collection stations have been established along the Etowah River. The sampling was carried out at two week intervals for two sampling periods and subsequently throughout the winter at four week intervals. The brush boxes are pulled every six weeks. This study should be particularly useful in the determination of the identity and location of organisms which would be useful as indicator organisms for continuous monitoring for biological accumulations of secondary radioactivity which would possibly wash from the reactor area into the stream.

E. *Small mammal studies.*

These studies are being carried out by the University of Georgia. Originally it was planned to determine the distribution, abundance, and reproductive performance of the small mammals on the reservation at the Lockheed Nuclear Reactor Site by a snap trapping and live trapping program. The data obtained for mammal populations affected by radiation within the 3600 foot fence could be compared with non- radiated control populations on other areas of the reservation. It was thought that a small mammal such as *Peromyscus leucopus* (the deer mouse) would be an ideal indicator species for the intensive study of radiation effects. However, in one month of field work only one deer mouse had been captured. Although it is probable that activity of these mice is affected by weather conditions, it is obvious that such sporadic catches make this species almost useless for our purposes as an experimental animal. Since the reservation lacks abundant populations of other small mammals, efforts have been recently concentrated on birds and larger mammals.

Eight feeding trays (4 control and 4 radiated) for birds have been erected. This will be the basis for further bird census studies. Forty nest boxes for flying squirrels (20 control and 20 radiated) were erected. The flying squirrel (*Glaucomys volans*) seems to be the most abundant mammalian species in the area. If the nest box tech-

nique is successful and the squirrel population proves to be sufficiently abundant, research efforts will be concentrated on this species. It will be interesting to compare litter success (which will be readily measurable by periodic checks on nest boxes as the season progresses) in the radiated and control areas. Research in home range, population density, population turnover, and energy exchange will also be conducted.

Larger mammals such as rabbits, foxes, and raccoons offer additional possibilities for study and it is hoped that some information on these can be obtained before the reactor becomes active.

F. *The effects of gamma radiation gradients on selected granite outcrop communities.*

This study is being carried out at Emory University. Selected communities from the granite outcrops will be moved to two experimental outcrops constructed in the cobalt 60 radiation field on the Emory campus. One will have radiation gradients from 100 r per hour to .5 r per hour, and the other, with lead screening, will serve as a non-radiated control. The studies will be oriented to effects on composition, physiological tolerances, competition and ultimately on succession.

G. *Cytogenetical effects of radiation on selected components of plant communities.*

The cytogenetical aspects of the program include first the study of plants in their natural habitat both for short range and long range effects of gamma and neutron radiation, and secondly the use of Tradescantia for measuring the effects from short exposures.

At the present time four collecting sites have been used. Three of these are along the south, east, and north radii from the reactor, and the fourth site is on the siding area. In the first three sites at least one has been selected for use for monitoring devices which will give the neutron and gamma radiation separately. Other monitoring devices which will yield only an integrated amount will be used at other places in the collecting area. The railroad siding area, which is a gamma field only, will be used in comparison with the other three sites.

On the north side of the reactor, beginning at approximately 750 feet and progressing up the slope to about 1500 feet, eleven species of plants have been sampled, ten specimens being collected from each species. On the south exposure, fourteen species of plants with ten specimens each have been collected from distances ranging from 500 to 2000 feet. On the east side, collections of eleven species of ten specimens each have been made ranging from 1000 to 2000 feet from the reactor. On the railroad siding five species of ten specimens each have been collected from the end of the railroad tract ranging from 25 to 200 feet.

In all of these collections, which were made last April, trees, shrubs, and herbs are represented. The trees, being above the ground, will

be continuously exposed during the reactor operation, and should give information concerning leaf buds and young developing leaves. The herbs should yield interesting results since many of them have above the ground shoots existing for only a short time during the year. Some of these herbs develop the first leaves and flower buds under ground, and in this way might yield some interesting information on the effects of secondary radiation in the soil.

A number of Tradescantia plants now in the green house are to be taken to the area during periods of reactor operation, and placed at all four stations. The use of this plant will provide immediate information relative to chromosome and cellular damage. Some of these plants will be placed on the site during off periods in order to determine if the background radiation induced during the reactor operation will be sufficiently increased to cause chromosome disturbances above that naturally occurring in the Emory University green house.

Experimental data in all cases will be obtained from temporary acetocarmine smear preparations. The material first will be fixed and preserved in alcohol acetic solution (3 parts absolute alcohol to one part acetic acid). This solution also acts as a preservative so that the material can be left in it for a year or more. In each of ten preparations which will be made from each of the ten different plants from each species, several metaphase and anaphase configurations will be studied in order to determine the occurrence of abberations. These data from the collections made prior to release of radiation in the area will serve as controls. Comparative materials can then be collected and studied at suitable intervals in the future.

H. *Use of dendrographs as a measure of whole tree response.*

A series of Fritts dendrographs will be installed on one or two species of trees along radiation gradients, and in comparable sites at the control field. An expression of two types of response will be sought, one for radiation effects during the period of radiation, and the other for radiation effects over long periods of time. The purpose of the dendrographs is to provide a chart of the fluctuations and growth of the tree trunk. The Fritts type is so sensitive that even hourly fluctuations are recorded. Although these fluctuations are integrated expressions of a variety of environmental factors, such as soil moisture, temperature, sunshine, physiological states, etc., these can be separated by multiple regression analysis of data, and the effects of radiation perhaps isolated. Over long periods of time growth curves are obtained which can more easily be correlated with radiation.

I. *Studies on soil microbiology, soil chemistry, and soil physics.*

These studies have been projected by the Department of Agronomy of the University of Georgia. Basic soil sampling will be done prior to release of radiation in the environment.

Soil Microbiology

Studies will be made in the area of soil microbiology on the effect of neutron and gamma radiation on: (1) the ecology of broad groups of microorganisms in soils; (2) a carbon dioxide production from soils; (3) the nitrogen fixing capacity of non-symbiotic and symbiotic nitrogen fixing bacteria; and (4) nitrification in soils.

Soil Chemistry

In the field of soil fertility and soil chemistry several aspects of high intensity radiation will be investigated. Some of the more promising appear to be studies of the changes in status of several plant nutrients. These will include the alteration of fixed mineral nutrients to exchangeable form; increased solubility of insoluable nutrient salts; and the mobility of various ions within the mineral structures. Other various uses of the radiation will include a study of the effect of radiation on the stability of common soil minerals, both as single minerals and in mixtures, representing the approximate mineral suites in the soils surrounding the reactor site. Thermal effects of the radiation on the moisture and gaseous diffusion gradients in soils and the fate of radioactive gases produced in the soil air should also be studied. Studies should also be conducted on the effect of high intensive radiation on specific ion uptake from differentially fertilized soils. Conversely, the effect of levels of soil fertility on the susceptability of various plant species to radiation effect would make a valuable contribution.

Soil Physics

In the area of soil physics the effect of neutron radiation on ion production and plant uptake as affected by soil moisture content and tension will be investigated. Further studies which should be rewarding would be the effect of intensive nuclear radiation on soil structure, soil moisture retention and movement. Other physical factors which affect root growth would also be investigated where they might be affected by radiation.

ATMOSPHERIC ELECTRICITY

R. GILBERT HENRY, *University of Georgia*

The earth's electric field acts only on charged bodies, in that it causes particles of air, dust, drops of water, etc., to move, if they are electrified, but does not affect uncharged ones. We will call this the earth's electric field. The potential of the atmosphere increases with height from the ground, therefore we shall speak of the earth's field in volts per meter in order to show the amount of change of voltage for one meter.

Under fair weather conditions, and on level ground where there are no trees or houses, the difference of potential between the ground and a man's head is several hundred volts, approximately the same voltage as the ordinary lighting voltage. From this, and electrical theory, we are led to believe that the earth is charged highly.

Observations show that the potential changes throughout the day and that the daily change is very similar in any one location. Some places show the daily change about the same throughout the year, but in most locations the daily change is different in winter from that in summer.

The Carnegie Institution of Washington has done extensive work in regard to the variation of the potential gradient from day to day, and from year to year, in all parts of the world. Their results show that a chief daily maximum tends to occur everywhere at about the same absolute time.

It is found that for most parts of the world, the average potential for constant conditions is greater from October to March inclusive, but there are some places where the reverse is true.

Air is a fair insulator, but it is far from perfect. It is known that air is made up almost entirely of molecules of nitrogen and oxygen. Most of these are electrically neutral, but a small number are charged, some positively and some negatively. The ones carrying positive charge are called positive ions, and those negatively charged are called negative ions. Negative and positive ions attract each other, and when two oppositely charged ions combine, their charges neutralize and become ordinary air particles. We see that the ions are constantly disappearing, and unless there were a source of supply, the air would soon become non-ionized. Ions are being formed at a rapid rate under ordinary conditions.

The electric field of the earth causes the positive ions to travel toward the ground and the negative ones to travel up at the rate of about an inch per second. Therefore, we have an electric current from the air to the earth.

There have been a number of interesting speculations as to the causes of this phenomenon. Sehncke showed that the friction of small particles of water against dry ice was a source of electricity, and thus he decided that the atmospheric electricity might come from the upper regions where there might be both water and ice; the ice particles

becoming positive and the water negative, and the water when falling as rain would carry the negative charge to the earth.

There is a radiation coming from outside space which is akin to x-rays, except that it is more penetrating and its effective wave length much shorter than the x-rays usually generated by ordinary means, or even gamma-radiations of radioactive material. These radiations have been called "penetrating radiation," and are thought to produce ionization.

Another cause affecting the change of the potential of the earth's field comes about with the appearance of sun spots and their change in intensity.

It is also known that small amounts of radium and thorium are present in the air. This material and sunlight are believed to be partly the cause of the formation of ions.

A general conductor placed in the air does not take on a potential readily; it is therefore convenient to use a sharp point, flame, or dropper, and in recent years, a wire tipped with some radioactive material has come into use. A wire prepared in this way is called a collector. The author has used such a wire with a small quantity of radium chloride fastened to it with shellac.

It is known that potential varies with height. The author found, in common with other observers, that the potential varies irregularly with height in unsettled weather. However, when the weather is steady, the potential gradient varies practically linearly with heigth. There were about six hundred readings taken during all kinds of weather conditions.

It was note that the presence of some clouds causes the potential of the point in the air to assume a very high negative charge with respect to the earth. There was a violent rain and wind storm immediately following a high negative charge. In every case when snow was on the ground, the air became highly charged with positive electricity. During heavy rain, the potential becomes equal to that of the earth. During fair weather, the potential graually rises in the morning, assuming a chief daily maximum shortly before noon, and then gradually recedes. In some cases, light rain brings down negative electricity. The presence of some clouds caused an irregular potential, changing haphazardly during the day.

The following conclusions have been drawn from the experiment.

The atmosphere is almost always electrified, the charge generally being positive. There are great variations of this charge. Under most conditions, and especially during fair weather, the intensity varies with the hour of the day, tending to reach a chief daily maximum shortly before noon. The intensity of this electrification, during fair weather, varies almost linearly with height above the earth, but when unsettled conditions exist, there is no such linearity.

The presence of clouds has a great effect on the electrification, causing it to assume sometimes a positive and sometimes a negative value.

A light rain usually causes the potential to become negative with respect to the earth, and a heavy rain causes it to become zero.

After snow has fallen, the air assumes a higher positive charge that usual.

In this study, no relation could be found as to how the intensity varies with pressure and temperature.

AN OBJECTIVE INDICATOR OF IMPROVEMENT DURING PLAY THERAPY

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While using doll play with disturbed children, the writer observed that some subjects evidence a desire to put the greatest possible distance between themselves and the disliked person, as represented by a doll. Other youngsters prefer to mutilate or give physical punishment to the dolls standing for the hated individuals, while still others verbalize their feelings. In some instances the child utilizes all of these manifestations.

Several attempts have been made by the writer to study a child who consistently wished to put the rejected doll at a distance, but for various reasons these studies were not completed. The present report is the first which was continued over an adequate period of time, with satisfactory records.

Since the current study is based upon a so-called case of paralysis with loss of locomotor ability, it is especially appropriate to investigate the subject's reactions to space, or distance.

The subject:

The child, Jane, was six years of age when she was referred to the writer by her physician. Seven weeks prior to the referral the child had had what was first diagnosed as poliomyelitis, with a concomitant loss of ability to walk. After numerous trips to specialists, the family was told by medical examiners that there was no neurological basis for the child's condition. At this point she was brought to the Psychological Clinic.

On Jane's initial visit she was carried in her father's arms. At first her behavior was markedly infantile, with much crying and even baby talk. It was necessary to win her confidence before she could be separated from her parents.

With the approval of the child's physician, the parents and the child were taught several games by which her legs could be exercised. A pet, a tricycle, and frequent visits of friends were recommended as diversions for Jane. Therapy sessions were scheduled twice weekly through the twelfth interview, and thereafter once weekly, until walking was considered to be occurring normally, at which time the parents decided to discontinue regular sessions. Later interviews were scattered over a period of six months and were scheduled by the therapist to ascertain the child's status, which remained normal. The child's parents kept written records which they brought to the inter-

views. A graduate student talked with the parents while the writer worked with Jane, and then the roles were reversed. The student kept no therapy records, however.

The first two sessions were held with the parents present and these are not included in Table I. During the third visit it was possible to see the child alone for approximately twenty minutes, and this is recorded in Table I as the first session. In this table only the odd-numbered interviews are recorded, inasmuch as they appear to be representative of the total.

The length of the play-sessions varied from fifteen to forty-two minutes, the duration being determined by the subject, but within the limitation of fifty minutes.

The therapist utilized the non-directive, client-centered approach during the play sessions.

Recording of distances was facilitated by the use of a floor covering of the checkerboard type in the doll house, each space being one inch in size. The floor in the therapy room was covered with material divided into sections nine inches square. Frequently used measurements were posted conspicuously on the wall in front of the therapist.

Jane's family consisted of father, mother, a brother of twelve years, Jane aged six years, and a little brother four years of age. Jane was quite jealous of the younger brother who was a family favorite, taking much of the mother's time. Her parents described Jane as having always been a "nervous child."

Just prior to the supposed attack of polio, Jane had had a series of disappointments and frustrations. During this period she mentioned frequently that she was afraid she might die. The so-called paralysis occurred soon thereafter in a convalescent period following an attack of sinusitis and tonsilitis. Jane suddenly collapsed, saying that she could not walk. For a day or so she continued locomotion in the form of hopping, and holding onto people, or objects, for support. At this point she was taken to see several medical specialists.

Discussion of results:

As shown in table I, the subject's reactions to the doll representing the younger brother reveal a gradual increase in the average distance from the subject to the doll, until a maximum of 72 inches is reached in the seventh session. In the early sessions it appeared that Jane was afraid to give free expression to her feelings. The permissive attitude of the therapist apparently reassured her that she need not inhibit or conceal her hostility. In interviews 5, 7, and 9, the distances averaged 64, 72 and 60 inches, respectively. At this stage more verbalizing also occurred. For instance, Jane made frequent statements of this type to the doll representing her younger brother: "No, you gotta stay outside. Just me and Mommy and Daddy can be inside." The intensity of action also increased in sessions 5, 7 and 9, the brother doll being thrown with considerable force against the wall on two occasions.

It seems probable that actual, gradual improvement is indicated in the last five sessions, if the distance of the brother doll from Jane

Table I

Average Distances of Sibling Doll and Mother Doll from Subject During Ten Therapy Sessions

Session	DISTANCE (INCHES)				Motor Status
	Sib	Place	Mother	Place	
1	27	In	20	In	Inactive (A)
3	45	Both	32	In	Pushes legs (B)
5	64	Out	66	Both	Crawls (C)
7	72	Out	47	Both	Tricycles (D)
9	60	Out	51	Both	Pulls up (E)
11	41	Both	39	Both	Walks if holding (F)
13	49	Both	33	Both	Walks if holding (F)
15	35	Out	30	In	Walks alone
17	28	In	26	In	Runs
19	21	Both	17	In	Normal

(A) Inactive means that there was no crawling, walking, or use of legs for locomotion.
(B) Child pushed legs against adult's hands in rhythm.
(C) Crawling, mainly by pulling with arms; pushed self in swing, also.
(D) Rode large tricycle using one foot, mainly.
(E) Pulled up and stood, holding to a support.
(F) Walked if holding to a support.

is used as evidence. In table I, under "Motor Status", it will be noted that walking is coincident with the last five therapy sessions. In table I new achievements are listed in the last column.

Also in table I are given data regarding the average distance of the mother doll from the subject. On one day only, the fifth interview, was this doll placed farther away than was the brother doll. Although there was obvious hostility toward the mother, it was either not as intense, or fear prevented the free expression of feelings. The peak of "mother-resentment", if distance be used as a criterion, was reached in interviews 5, 7 and 9, as was the case with the brother doll. In like manner, the last five sessions were characterized by bringing the mother doll closer, and this was concomitant with the child's resumption of walking.

It seems reasonable to think that placing a doll outside of the house might be evidence of rejection. In table I, placement inside the dwelling is indicated by "In", and outside by "Out." If both placements occurred during a session, this is designated by "Both.' The rejected brother doll was kept in the house only during two sessions, the first and the seventeenth, while he was put outside during four entire interviews.

On the other hand, the mother doll was kept in the house for five sessions, and she was never left outside during a full interview. Four of the periods when the mother doll was kept outdoors for part of a session coincided with those having the greatest distances between Jane and the mother doll.

Summary:

A child who had not walked for seven weeks, although no neurological basis was found by medical specialists, was seen in regular therapy sessions covering fourteen weeks. In these sessions, records were made of the distances between the child and the disliked persons represented by the dolls. In general, after the child felt free to express her hostility, the decrease of distance was concomitant with psychological improvement, attested by progress in locomotor ability.

Since there are some children who evidence a desire to put the greatest possible distance between themselves and the disliked individuals, therapists may be able to utilize measurements of distance, as described herein, as evidence of progress in therapy. More research is needed to investigate the validity of this indicator of improvement.

A REDEFINITION OF OPERATIONALISM

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The general endeavor of a science is to present a system of symbols which are claimed to be representative of the realm of events that is within the province with which the particular science is concerned. These systems of symbols are defined variously by the logicians of science. These different ways of defining the systems are associated with different schools in the area of the logic of sciences. Among these schools are the Logical Positivists, the Conventionalists, the Realists, etc. The most controversial school in our time is that of Operationalism.

I should like to comment upon "operationalism" . . . its nature, its historical significance, and its critics, who have caused a change in its tenets. Of the various theories of scientific concepts, "operationalism" is the most recent to catch fire not only among the philosophers of science and scientists, but also among English and Law professors as well.

The movement started this way: In 1927, a physicist, Bridgman, said that failure in his preconceptions in many practical situations led him to attempt an establishment of a critical theory of scientific concepts. His theory of scientific concepts, viz, operationalism, had in 1927, as its fundamental dictum: "The scientific concept is synonymous with the corresponding set of operations." He gives many examples, the most quoted being that of length: "The concept of length is synonymous with the set of operations involved in measuring a given length." Unfortunately he does not mention which were specifically the practical situations that led him to formulate his theory, but he does cite Einstein's theory of simultaneity as the first example of operationalism, thus making as his

disciple one of the world's greatest physicists. The only difficulty is that Einstein was simultaneously claimed by the Idealists and the Whiteheadians as a charter member of their clubs, while Einstein himself seemed to want to join the school of Henri Poincare.

As far as I can tell operationalism didn't catch fire in the scientific world until after it had been severely criticized by such physicists as Margenau and Lindsay. In spite of the criticisms the theory has found a great many adherents among the social scientists, especially in certain branches of psychology . . . becoming in most cases methodological behaviorism . . . although it has even been applied to Freudianism. Oddly enough, it has been noted that the physicists weren't in much need of such a theory and it seems in fact to have had little effect in this area, except that I find that many elementary physics and chemistry teachers offer this theory as *the* theory of scientific concepts.

I should like to consider some of the criticisms that have been leveled against operationalism to bring out the serious inadequacy to the early formulation and to show the present mild position of operationalism:

Firstly: According to the dictum the concept must *mean* the set of operations involved. It does not mean the resultant length, but rather the actual making and applying some devices in the determination. Now Bridgman surely didn't mean to have such an activistic physics or science. In fact in 1950 he was led to change the dictum to say that the operational procedures involved in the determination of the meaning of a concept certainly are of great importance rather than they are synonymous with the concept.

Secondly: An operation is performed at a time and a place. Thus, strictly speaking, all operations differ to some degree in time and place. Hence we would have two different concepts with two different measurements. If this is the case then one can't use a generalized concept say of length . . . rather we would speak of length^1 and of length^2, etc. One would think that Bridgman would presumably want to hold that to the degree to which operations are similar they may be defined as the same concept, but he never makes this concession. This continued emphasis on particularity is a continued inadequacy in operationalism.

Thirdly: The importance of "mental" operations in the construction of scientific concepts, almost ignored in the 1927 position, was finally realized by Bridgman so that in 1950 he broadened operationalism to include as acceptable concepts not only directly verifiable operational concepts at length, but those indirectly inferred, such as anti-matter; those possible in principle, such as statements about the mountains on the other side of the moon; and, finally, but not least, those concepts which heavily involve the "mental" or "paper and pencil" operations, i.e., operations involving mathematics, logic and/or languauge

in their determination. The opening of the meaning gates so that all of these types of operations are considered part of the acceptable kinds of operations by the theorist shows Bridgman's abandonment of strict operationalism for a rather mild form. This mild form differs from such theories as fictionalism and conventionalism in part by the fact that Bridgman doesn't allow the purely conventional concepts to be admitted to the realm of science. And here lies another problem for operationalism, namely the status of concepts which cannot possible be verified . . . such as perfect engines, absolute zero, frictionless planes. These are valuable scientific concepts . . . concepts which any theory of scientific concepts must account for within his system . . . concepts which must be accountable for within the operationalist theory for the system to be adequate.

Finally: Bridgman and the operationalists seem not to fully realize that operations *per se* are not actualities to be simply accepted. Scientists perform on the one hand very bad operations and the resultant data are therefore quite unreliable; on the other hand they often throw out data held to be unreliable because they do not fit the suspected curve. Think how many white rats have been guillotined because their digestive data lay to one side of the speculated curve region. Everyone realizes, even Bridgman after criticism, that there are "good" and "bad" operations, but no criteria have been suggested. Operations must thus be subject to some criteria . . . beyond the operations themselves. Consider, for example, the launching of a weather transmitting radio into space via a balloon. This instrument is called a radiosonde, and transmits signals back to a receiving instrument, which electronically records, when working correctly, data which can be decoded into temperature, pressure, and humidity. The procedures involved in operating the entire radiosondic apparatus is quite complex . . . hence errors in operations can occur at several places: The original equipment can be faulty, the launching procedure can damage the transmitter, radio interference often occurs, the staff operating the equipment and deciding the data is too often known to err. These and many other "bad" operations can occur. Similar operational difficulties could be listed for any scientific experiment. On the basis of the above discussion we can list some of the criteria for a "good" operation: namely the instruments must be functioning properly, the data must be within the limits of the tolerance of the instruments; the environment must not significantly affect the data; and finally the operator's limitations must not create erroneous data. Hence the operationalist must not accept operations *per se* as ultimate, but should allow only "good" operations.

In Conclusion: The operationalist should reaffirm his dictum as: "The determination of the meaning of a scientific concept *involves good mental* and *physical* operational procedures." This

will make the theory more adequate, although the theory must still handle the problems of generalization of concepts and of non-verifiable concepts . . . problems which seem to create severe difficulties within the general operationalist theory.

ON GRAVITY AND GROWTH

The Dynamic Response to Gravity by Growing Plants[1]

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Inanimate objects move against the earth's gravitational field only when propelled by forces external to themselves. In nature, the ejectae of volcanoes, the water of artesian springs, and mountains uplifted by crustal movements are the more obvious examples. Living creatures have found other means of overcoming this ubiquitous force. Birds fly; men can throw stones or shoot arrows. Such activities have been analyzed, and put to man's use in extremely sophisticated ways.

Another more widespread, method for overcoming gravity displayed by living things has passed nearly unnoticed and completely unstudied until very recently. So common is it, we rarely observe that the great majority of higher plants and animals actively resist the pull of gravity by the application of forces within their own bodies. Most striking are examples in the plant kingdom where great trees witness that tons of material have been lifted scores of feet above the earth.

This overcoming of gravity is the result of growth forces. Growth requires energy for many processes, some only poorly understood; but we can measure, quite exactly, that energy used in overcoming gravity. If a wheat seedling sprouts and grows four centimeters in four days, and has then a weight of 0.05 grams, it has accomplished $0.05 \text{ gm} \times 1 \text{ G} \times \frac{4 \text{ cm}}{2}$ or 0.1 gram centimeters of work in four days. Since at least half of this growth is accomplished on the third day, the work rate reaches more than 0.05 gram-centimeters in twenty-four hours.

This is neither the greatest nor the smallest work output among plants. Bamboo grows far faster and many creeping plants grow upward very little. The wheat seedling is, however, a convenient research object. Its first shoot, called the coleoptile, has a four day

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[1]Prize winning essay submitted to the Gravity Research Foundation for its 7th annual award (1956). Read before the foundation at New Boston, New Hampshire August 18, 1956 by Stephen W. Gray, B. A. (Lake Forest) '36, M. A. (Illinois) '38, Ph. D. (Illinois) '39. He is Associate Professor of Anatomy

life span and a simple structure. Nearly all of its growth is upward and can thus be evaluated by a single measurement.

We have long known that the growing plant orients itself with respect to gravity due to the downward diffusion of growth stimulating substances (auxins) from the tip. We have not understood that there is a quantitative growth response to gravity as well as a qualitative one. If the only dynamic response were orientation, we might expect a plant grown in an environment of twice the earth's normal gravity to be half as high.

By growing wheat seedlings in the centrifuge in the dark (to use respiratory energy free from photosynthesis), it is easy to vary the gravitational forces exerted on the plant. The very simplest experiment will show that growth is not readily depressed by increasing the work load. At two times gravity there is no observable difference in the height attained by the mature coleoptile. If we increase the gravitational fieild sufficiently, we find that we are finally growing shorter seedlings, but, by the time we have reduced their height to one-half of normal, we are imposing a force of *500 times* earth's gravity. Beyond this we cannot go. Growth does not fail, but the structure has reached its mechanical limit, and the hollow, oval coleoptile buckles and breaks.

The structure does not fail without an adaptive response, which, although inadequate in the long run, is not insignificant. In the increased gravitational field, the young shoot increases its diameter and hence its cross-section area. At 150 times gravity this increase amounts to 37.9% in cross-section, 54.6% in moment of bending and 16% in actual resistance to bending forces at right angles to the long axis.

In addition, while the dry weight of control plants is 9.35% of wet weight, at 150 times gravity, the percentage has become 10.72. More solid material has entered into the construction.

These factors must be taken into account in considering the work response. If actual weight raised to actual height be calculated as gram centimeters of work done, we find that the increase in work in relation to the force of the gravitational field of the plant's environment is linear and proportional for all forces up to nearly 100 times gravity. That is, the growing plant compensates almost perfectly for the increased force (figure 1).

Beyond this point, compensation fails to keep up with further increase in the force of the field, but work output continues to increase at a lower rate. At 500 times gravity plants are doing about twice the work of those centrifuged at 100 times gravity.

The work done against gravity over the whole four days does not bring out the entire picture. More work is done during the later half than the earlier for exactly the same reason that more work is expended laying brick at the third story of a building than at the second, and more at the second than at the first, because the bricks must always start from the ground. The following table will show the relation between growth and work done in an average of 650 normal wheat seedlings.

TABLE

Comparison of Growth and Work Accomplished During Maturation of the Normal Wheat Coleoptile

Time	Growth	% Growth	Work Done	% Work Done
1st day	3.5 mm	8.65	7.15 mg mm.	0.75
2nd day	5.76 "	14.24	42.94 " "	4.49
3rd day	21.88 "	54.08	516.31 " "	53.97
4th day	9.32 "	23.03	389.86 " "	40.79
Total	40.46 mm	100.00	956.26 mg mm	100.00

About 95% of the total work is accomplished in the last half of the period but only 77% of the growth takes place. During the first day, when growth is starting, the percentage of work done is nearly negligible. Increasing the gravitational field to fifty times normal during this first day results in a work load of 357.5 mg mm (50 x 7.15 mg mm). This is less than the 389.9 mg mm work load on the fourth day under normal gravitational conditions. It suggests that centrifugation at 50 times gravity during this period will not overtax the plant's resources.

Experiments to test this hypothesis show that growth is not inhibited under these circumstances, but is, on the contrary, *stimulated*. By the 60th hour, plants centrifuged for the first twenty-four hours are 3.64 mm or 19.4% taller than control plants of the same age. This effect is observable at lower forces; 10 times gravity produces 5.67 mm or 30.2% increase in height, and even at 500 times gravity there is a slight, but not statistically significant, increase of 0.32%.

Similar centrifugation performed on the second, third and fourth days of the coleoptile's life does not produce this stimulatory effect, but instead, inhibits growth during the period of centrifugation and for about twenty-four hours afterward. Rates for each of the four days are shown in figure 2.

It is reasonable to conclude that the increase in the gravitational field places little strain on the plant's work capacity during the first day, but later, when normal work output is greater, the strain becomes intolerable and decreased growth results.

There is another aspect of work done which has not been measured in these experiments. Height attained is the record of building blocks raised to their position and left there. Water of transpiration is also raised against the pull of gravity; the work involved in this process is likewise multiplied by the environmental force. This water, evaporating from the coleoptile, is not here considered, but must not be forgotten as it is involved in the growth process, just as is the work required for the brick-layer to lift himself to the

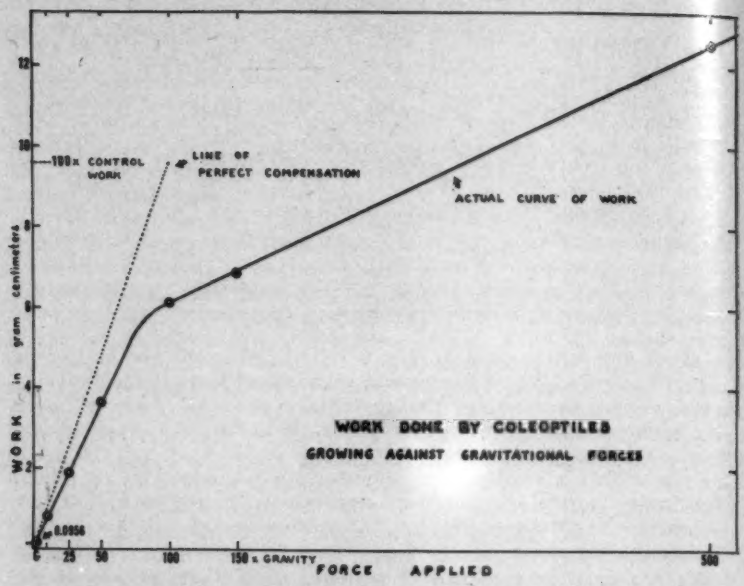

FIGURE 1. *The work output response of wheat coleoptiles grown for four days under various gravitational forces. Control plants (1 x gravity) do 0.0956 gm cm work in growing 4.06 cms. The dotted line represents theoretically perfect compensatory response.*

upper stories of a building under construction, even though no bricklayers remain in the completed building.

One can reasonably imagine the means by which the increased gravitational field interferes with cell elongation. The compensatory mechanism, making more energy available to overcome gravity, is by no means so easily explained. At present, one can only take refuge in the doctrine of homeostasis, and observe that this response to changes in gravity is similar to the efforts of all organisms to maintain their integrity in the face of changing environment.

Such a mchanism must also account for the increased growth observed in plants centrifuged during the first day of life. The homeostatic controls, having been adjusted for a gravitational field of a certain strength, do not respond at once to the reduction of the field to "normal" at the end of twenty-four hours, but continue, for some time, to demand the same output of energy which now produces greater growth in the weaker gravitational field.

The analysis of the response of living things to gravity has barely begun, and we have not yet had time to formulate hypotheses regarding the mechanics of the observed changes. When we have

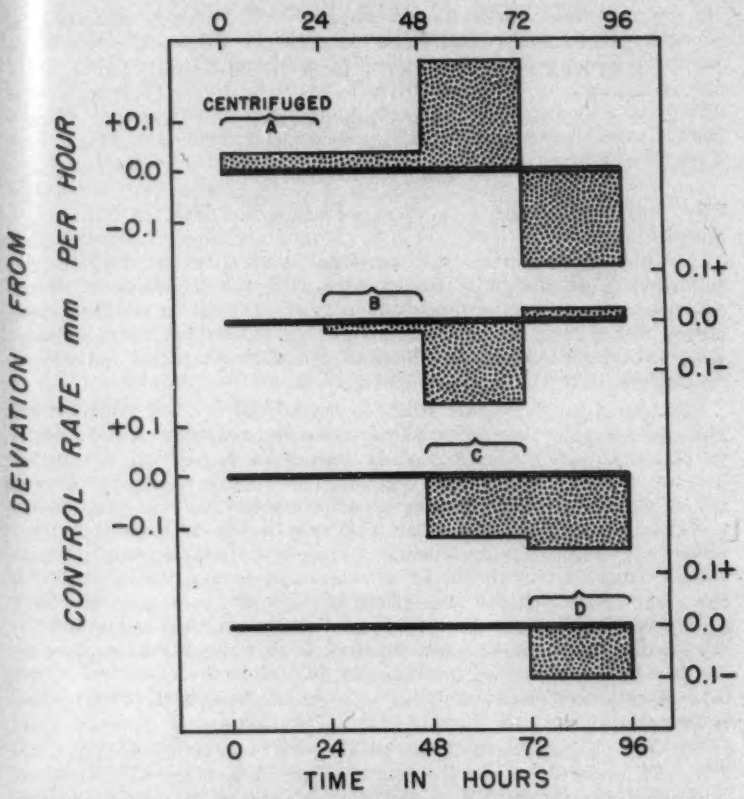

FIGURE 2. *Growth rates of wheat coleoptiles centrifuged at 50 x gravity on each of four different days. Shaded blocks indicate faster or slower growth than that of control plants indicated by heavy black horizontal line. Note that in A, normal height has been achieved earlier than in controls so growth from 72-96 hours is very small.*

learned more, we may be in a position to apply our knowledge to problems of plant and animal growth.

To speculate, one might suggest that a way may be found to increase the relative dry weight and hence the strength of trees, thereby producing usable lumber from fast-growing but structurally weak species. In wheat itself, strength of mature stems is an important factor in minimizing wind and rain damage. Beyond these specific suggestions, it is hoped that work in this direction may shed light on the oldest, most inscrutable of biological problems, the control of the *form* of living organisms and especially the role of gravity in this control.

STUDIES IN RADIATION ECOLOGY: II. PLANT COMMUNITIES OF A 10,000 ACRE EXPERIMENTAL AREA IN NORTH GEORGIA[1], [2]

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INTRODUCTION

The objectives of the study are first to identify and map the distribution of several plant communities over the 10,000 acre reservation and secondly to obtain data on the composition of their overstories. This study is an integral part of a comprehensive research program on the ecological effects of radiation on man's natural environment. (Platt and Mohrbacher, 1959).

The significance of this study is three fold. (1) It characterizes and describes the vegetation of the area in a way that will be useful in planning and evaluating other studies to be carried out in the area. (2) By describing the vegetation as it now exists by methods which may be repeated, changes occurring in the next ten, twenty or thirty years may be defined. This may be of extreme importance in terms of the diversity of studies projected. (3) This study constitutes a vital unit in the series of maps and surveys being made for the area. These include: vegetation, topography, soils, geology, background radiation, patterns of induced radiation, and microclimates. Its significance then, in another sense, is that the ultimate objective of the whole program of studies is to determine the biological effects of radiation, and this is the only survey of those just named which is biological.

The experimental area is the 10,000 acre reservation of Air Force Plant 67, operated as the Georgia Nuclear Laboratories by Lockheed Aircraft Corporation. The reservation is located in Dawson County in the upper Piedmont Province. The area, approximately square, is surrounded by a barbed wire fence inside of which is a firebreak forty feet wide. The site has been undisturbed, except for official work, since completion of the fence in September, 1957.

The upper Piedmont is part of an ancient peneplain where erosion by numerous streams has resulted in typical rolling, well-dissected topography. On the reservation the underlying gneiss and schist have been pushed up into a series of ridges that extend in a northeast-southwest direction with a total relief of about 400 feet. The

[1]This study was supported in part by a research grant (At-(40-1)-2412) from the Atomic Energy Commission. The U. S. Air Force and Lockheed Aircraft Corporation generously provided the facilities necessary for carrying out the study on their 10,000 acre reservation near Dawsonville, Georgia.

[2]This paper is based on a thesis submitted by the senior author to Emory University as partial fulfillment of the requirements for a Master of Science degree.

soils are characteristically residual, only a small portion being alluvial or colluvial. The entire reservation is drained by the Etowah River which rises in the Blue Ridge and enters the Alabama-Coosa River system at Rome, Georgia. The Etowah and its tributaries are actively down-cutting throughout the area, even though they are bordered in some areas by narrow strips of flood plains. Shoal Creek and the Amicolola Creek are the principal tributaries of the Etowah within the reservation.

The climate of the area is temperate and continental, the mean annual temperature being approximately 60°F. with short cool winters and warm summers. Extreme temperatures of 100°F. and 0°F. occur only in occasional years. The average rainfall is about 56 inches at Dawsonville, the site of the nearest weather station. The heaviest rains occur in the winter and spring, but the rainfall is fairly well distributed during the year. The current development of a network of micrometeorological stations in the area will provide highly significant data for future studies.

The early history of the area is well known and is similar to other regions in the upper Piedmont. This section of the country was opened to white settlers in 1832, the year that President Jackson moved the Cherokee Nation north of the Chattahoochee River to the west. A resident of the area relates that his great-great-grand-father who was one of the early settlers described the forests as mostly deciduous. The understory was annually destroyed by the Indians with fire. Nelson (1956) in reviewing the early literature gives a more accurate picture of the vegetation. He found that about 40 percent was a pine-hardwood mixture and another 35 or 40 percent was primarily hardwood. The remainder consisted of about 15 percent pure pine and small areas of rock outcrops and "glades" of blackjack oak. The land was quickly cleared and cotton planted as the commercial crop. Improper management permitted destructive erosion and many farms were abandoned in the late nineteenth and early twentieth centuries. Subsequently these abandoned farms have reverted slowly to forest land by way of the typical patterns of secondary succession as described by Bard (1952), Keever (1950), Oosting (1942), and Quarterman (1957).

Although no community composition studies have been conducted in the Piedmont of Georgia, the works of Braun (1950) and Oosting (1942) are important as general ecological studies in this type of area. Braun describes the area as a mixture of oak and pine. She states that pine is abundant in the poorer sites. Oosting's work was conducted in the Piedmont of North Carolina which is similar to the Piedmont of Georgia in many respects.

MATERIALS AND METHODS

The major plant communities were mapped using aerial photographs, contour maps, and field observations. The area was flown at 4,000 feet in the first week of May and again in the first week of June to obtain the series of aerial photographs. Black and white,

color, and infra-red photographs on 35mm, and 4 by 5 inch film were used in order to accentuate the differences between evergreen and deciduous communities. Aerial photographs by the Agricultural Stabilization and Conservation Department of the U.S.D.A. were used for making comparisons of the vegetation as it appeared in 1938, 1949, and 1956.

Almost half of the boundaries between communities were checked on the ground, the remainder being evident from the aerial photographs. In many cases the ground check was accomplished from a vantage point near the boundary in question, such as the tops of tall trees on hill crests, the water reservoir, and the 150 foot radar tower. The entire area was examined over a five months period from November to March before mapping was started.

After the communities were mapped, the overstories of those with tree dominants were sampled using the quarter or quadrant method as described by Cottam and Curtis (1956). This may be briefly described as a plotless method in which sample points are selected by pacing predetermined distances, usually along a compass line. For each point, the closest trees in each quarter is selected. The distance to the tree, its diameter at breast height, and the species are determined and recorded. In mixed stands forty points, 20 meters apart along parallel compass lines that conformed in length to the shape of the stand were used. The usual ecological expressions used in community studies may be determined by using one or more of the following formulae:

1. Mean distance equals $\dfrac{\text{sum of all distances}}{\text{total number of distances}}$
2. Mean area equals mean distance^2
3. Number of trees per acre equals $\dfrac{43{,}560}{\text{mean area}}$
4. Relative density equals
$$\frac{\text{number of individuals of the species}}{\text{number of individuals of all species}} \times 100$$
5. Number of trees per species per acre equals relative density of the species X trees per acre.
6. Average basal area per tree equals $\dfrac{\text{total basal area}}{\text{number of trees}}$
7. Basal area per acre equals number of trees per acre X average basal area per tree.
8. Relative dominance equals
$$\frac{\text{total basal area of the species}}{\text{total basal area of all species}} \times 100$$
9. Basal area per species per acre equals relative dominance X basal area per acre.
10. Relative frequency equals
$$\frac{\text{number of points at which species occurs}}{\text{total number of points}} \times 100$$

Four separate pine stands were sampled using only twenty sample

points in each stand, since they were almost pure stands of a single species of pine. Two stands of flood plain were sampled using forty points per stand. Four oak-hickory-pine stands were sampled by forty points in each case. Due to the small size of the trees in the pine stands all trees over two inches DBH were recorded, while four inches was the minimum DBH of trees recorded in the flood plain and the oak-hickory-pine communities. One of the typical upland disturbed communities with a cover of pine and deciduous seedlings was sampled using forty points. In the absence of large trees, the numbers only of individuals over one inch diameter at breast height were recorded.

The center of the sample stands are located by the following grid coordinates (Georgia grid system) as given on the topographical map prepared by Lockheed Aircraft Corporation for common use:

Oak-Hickory-Pine Stands			
North Slope	495,400	—	1,596,700
South Slope	502,600	—	1,583,500
Hill Top	509,000	—	1,580,600
Valley	496,600	—	1,583,400
Disturbed Area			
Upland Non-Cultivated Area	498,970	—	1,586,650
Pine Stands			
Short leaf pine I	498,800	—	1,583,180
Short leaf pine II	498,600	—	1,587,300
Loblolly pine III	505,500	—	1,583,100
Loblolly pine IV	493,500	—	1,580,500
Flood Plain Stands			
Stand I	499,500	—	1,588,900
Stand II	505,600	—	1,586,500

Observations on the understory, shrub, and herbaceous layers were made subjectively in the course of the sampling. Nomenclature follows that of Gray's Manual of Botany, Eighth Edition (Fernald, 1950).

RESULTS AND OBSERVATIONS

Four major plant communities were identified within the reservation area. These are, in decreasing order of occurrence, oak-hickory-pine, disturbed areas, pine, and flood plain. Their distribution over the 10,000 acre reservation is shown in figure 1. Aerial photographs of various parts of the area are shown in figure 2, and photographs of the four community types are shown in figure 3.

OAK-HICKORY-PINE

Oak-hickory-pine occuplies about 80 percent of the area and may be found in a variety of topographical situations. Stands on a north slope, a south slope, a hill top, and a small valley were sampled, the results being given in table 1. Part of this tabular data has been put in the form of phytographs and presented in figures 4 and 5.

The north facing stand is predominantly oak, with hickory and

pine making up only 6.2 percent of the relative density. Chestnut oak (*Quercus prinus*) is the most important species with 34.5 percent relative density, followed by scarlet oak (*Quercus coccinea*) with 26.2 percent and white oak (*Quercus alba*) with 15.6 percent.

The most important species on the south slope are post oak (*Querous stellata*) with a relatively density of 21.2 percent and

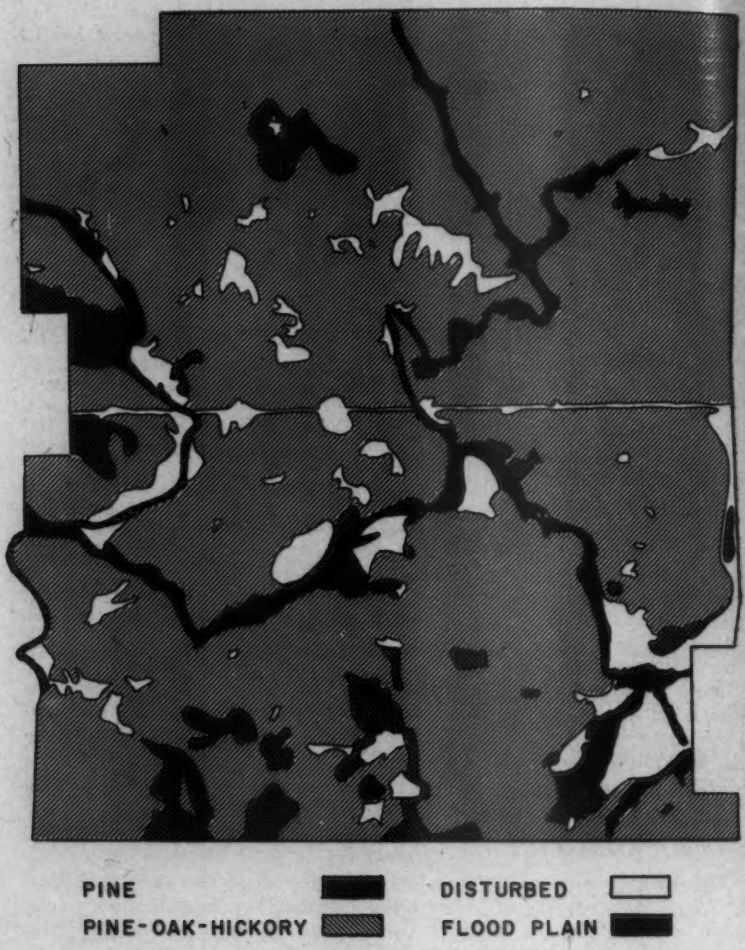

FIGURE 1. *Distribution map of the major communities of the* 10,000 *acre tract.*

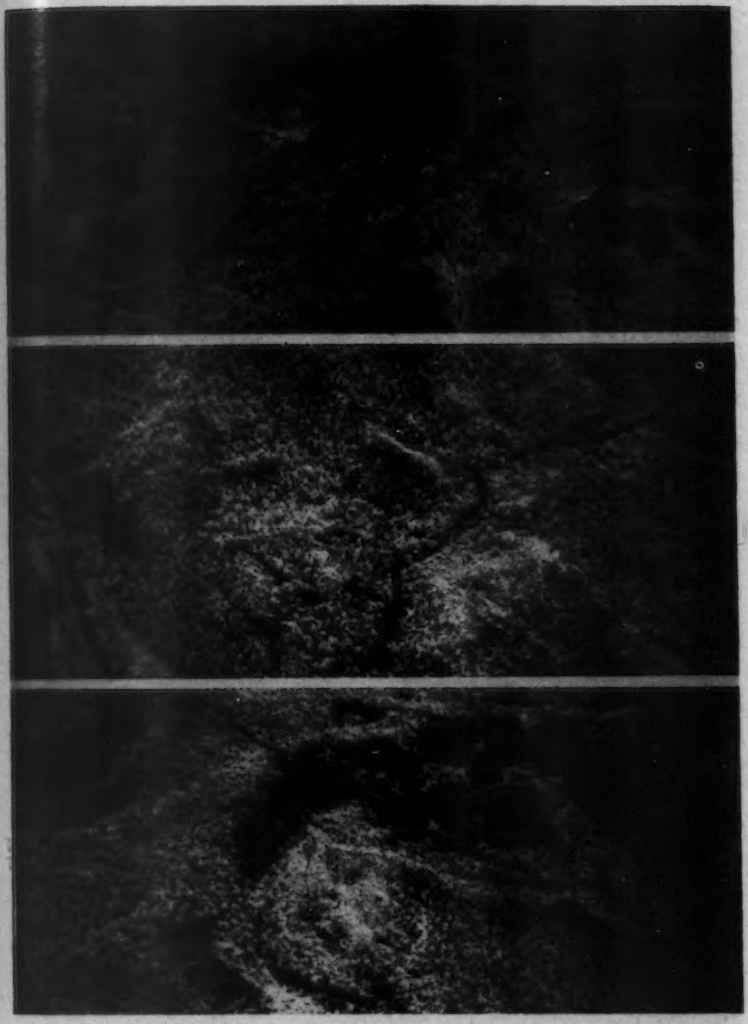

FIGURE 2. *Aerial photographs on infrared film of upper, middle, and lower portions respectively of the western side of the 10,000 acre reservation. All are facing east and were taken in early May, 1958. In the upper photograph is a typicial flood plain along the Amicolola Creek. In the middle photograph are stands of oak-hickory-pine, located above the confluence of the Amicolola Creek on the left and the Etowah River, with a very narrow flood plain, on the right. In the upper and lower photographs, the dark areas are pine stands.*

FIGURE 3. *Stands representative of the four kinds of communities described for the area. The upper left is a north facing slope of oak-hickory-pine, the upper right an upland disturbed area which has never been cultivated, the lower left the flood plain along the Etowah River, and the lower right a stand of short leaf pine, with an understory of hardwood saplings.*

short leaf pine (*Pinus echinata*) with a relative density of 21.9 percent. Other important species and their relative densities are mockernut hickory (*Carya tomentosa*) 15.6 and southern red oak (*Quercus falcata*) 10.9 percent.

Several species dominate the hill top community. The most impor-

TABLE I.
DATA FOR FOUR TOPOGRAPHICALLY DIFFERENT STANDS OF OAK-HICKORY-PINE

Species	Rel. Freq.	Rel. Den.	Trees/ Acre	Rel. Dom.	B.A./ Acre
Stand I (North Slope)					
Southern red oak	5	1.2	1.8	1.8	1.4
Scarlet oak	60	26.2	38.9	40	26.4
Post oak	7.5	1.9	2.8	.8	.4
White oak	47.3	15.6	21.7	12.1	7.9
Chestnut oak	67.5	34.5	51.3	31.7	20.9
Black oak	30	8.1	12	7.3	4.8
Pignut hickory	10	2.5	2.6	1.3	.9
Mockernut hickory	10	2.5	2.6	1.3	.9
Short leaf pine	5	1.2	1.8	.9	1.3
Tulip poplar	2.5	1.2	1.8	1.4	.9
Sourwood	2.5	1.2	1.8	.3	.2
Black gum	2.5	.6	.9	.2	.1
Red maple	5	1.2	1.8	1	.6
Persimmon	5	1.2	1.8	.5	.3
Serviceberry	2.5	.6	.9	.2	.1
Stand II (South Slope)					
Post oak	60	21.2	30.5	26.1	18.5
Southern red oak	30	10.6	15.3	15.5	11
White oak	10	3.1	4.5	5.4	3.8
Black oak	25	6.9	9.9	10.5	7.4
Chestnut oak	15	5	7.2	6.9	4.9
Scarlet oak	2.5	.6	.9	.7	.5
Pignut hickory	20	6.9	9.9	4	2.8
Mockernut hickory	40	15.6	22.4	17	11.4
Short leaf pine	57.5	21.9	31.5	7.4	5.2
Dogwood	15	3.8	5.5	1.1	.8
Ash	2.5	.6	.9	1.8	1.3
American Basswood	2.5	.6	.9	.3	.2
Persimmon	2.5	.6	.9	.5	.4
Sourwood	7.5	1.9	2.7	1	.7
Stand III (Hill Top)					
Post oak	47.5	17.2	22.9	20	10.6
Southern red oak	40	15	20	11.9	6.6
White oak	40	14.3	19	15	7.9
Black oak	20	7.2	9.6	7.3	3.9
Scarlet oak	22.5	7.5	10	6.4	3.4
Pignut hickory	42.5	15	20	19.7	10.4
Mockernut hickory	32.5	11.7	15.6	15	7.9
Short leaf pine	20	6.2	8.2	2.8	1.5
Scrub pine	2.5	.6	.8	.1	.05
Dogwood	5	1.9	2.5	1	.5
Sourwood	2.5	.6	.8	.2	.1

TABLE I. (cont.)
Stand IV (Valley)

Species	Rel. Freq.	Rel. Den.	Trees/ Acre	Rel. Dom.	B.A./ Acre
Southern red oak	15	4.3	10.8	4.2	3
Scarlet oak	70.3	30	75	32	22.3
Post oak	45	13.7	34.3	20.1	14.3
White oak	35	11.2	28	16.7	11.9
Blackjeck oak	22.5	8.7	21.8	6.1	4.3
Chestnut oak	22.5	10	25	9	6.4
Black oak	10	2.5	7.3	1.2	.9
Pignut hickory	10.3	3.7	9.3	1.9	.6
Mockernut hickory	5	1.2	3	1.3	.9
Short leaf pine	27.5	6.2	15.5	2.8	2
Scrub pine	5	1.2	3	.5	.4
Tulip poplar	2.5	.6	1.5	.5	.4
Dogwood	2.5	.6	1.5	.3	.2
Sourwood	2.5	.6	1.5	.3	.1
Black gum	5	1.2	3	.3	.2
Red maple	2.5	.6	1.5	2.8	2

tant of these and their relative densities are post oak 17.2, pignut hickory (*Carya glabra*) 15, southern red oak 15, white oak 14.3, and mockernut hickory 11.7 percent. Short leaf pine composes 6.2 percent of the relative density of this stand.

Scarlet oak with a relative density of 30 percent is the most important single species of the small valley community. Other important species and their relative densities are post oak 13.7, white oak 11.2, and chestnut oak 10 percent. Pine and hickory combined compose 12.3 percent of the relative density.

The more common understory species in these oak-hickory-pine stands include sourwood (*Oxydendrum aboreum*), dogwood (*Cornus florida*), black gum (*Nyssa sylvatica*), and persimmon (*Diospyros virginiana*). Infrequent species are serviceberry (*Amelanchier canadensis*), sassafras (*Sassafras albidum*), and wild black cherry (*Prunus serotina*). The only abundant shrubs are American tea plant (*Ceanothus americanus*) and blueberries (*Vaccinium spp.*), and the most common vines are species of greenbriar (*Smilax*). Rhododendron (*Rhododendron spp.*), grape (*Vitis spp.*), and honeysuckle (*Lonicera japonica*) are locally abundant. Common herbs found in most stands are species of grass (*Gramineae*), beggar's tick (*Desmodium*), hawkweed (*Hieracium*), potentilla (*Potentilla*), skullcap (*Scutellaria*), aster (*Aster*), lespedeza (*Lespedeza*), tickseed (*Coreopsis*), golden rod (*Solidago*), hoary pea (*Tephrosia*), and golden aster (*Chrysopsis*).

DISTURBED

Although most of the reservation has been disturbed to a great extent, the disturbed areas are defined here as those which have been essentially cleared of tree species. These communities represent about 10 percent of the total area and may be classified according

to their past history. Some are fields that have been abandoned in the last five years and are now occupied by annuals and very young pine seedlings. Others have resulted from the lumbering of pure pine stands in the last five to ten years as is evident in the aerial photographs obtained from the U.S.D.A., and may be subdivided on the basis of whether or not they have been cultivated. The non-

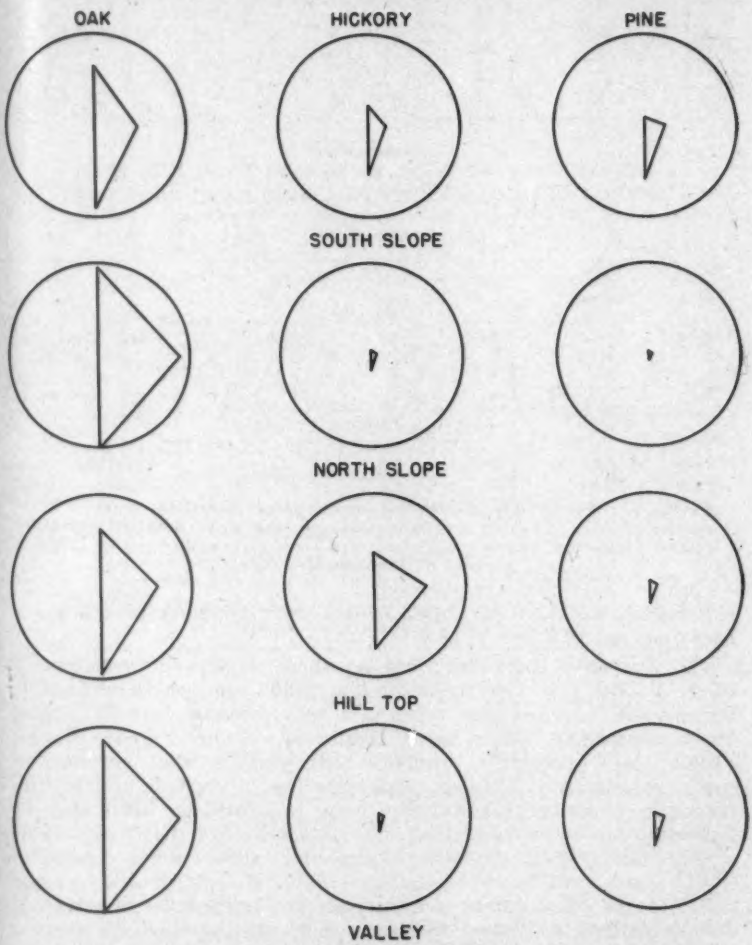

FIGURE 4. *Phytographs illustrating topographical variation between dominants in the oak-hickory-pine community. The top axis is dominance, the right density, and the bottom frequency. Each radius is scaled from zero at the center to 100 percent at the circumference.*

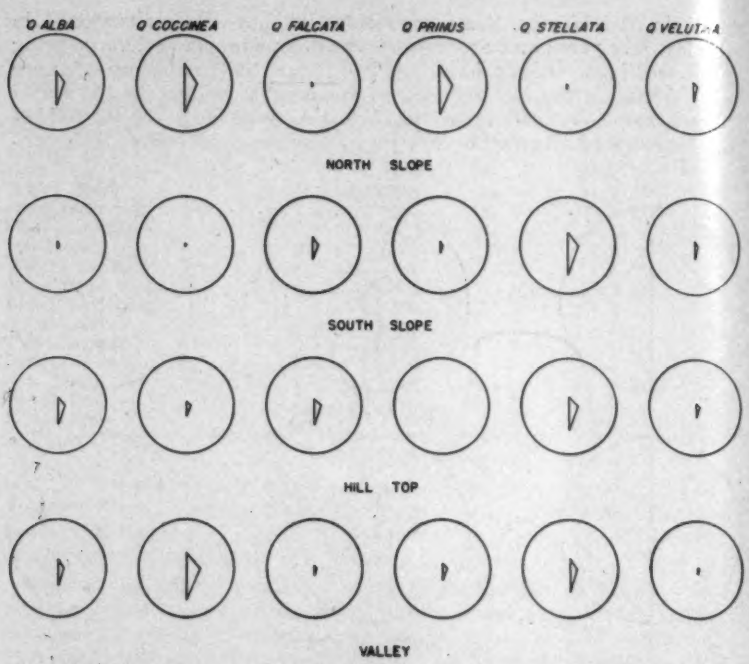

FIGURE 5. *Phytographs illustrating topographical variations between six species of oak. The top axis is dominance, the right density, and the bottom frequency. Each radius is scaled from zero at the center to 100 percent at the circumference.*

cultivated areas have developed an immature overstory that is about half pine and half oak (Table II).

The disturbed community has no shrub layer, but occasionally sumac (*Rhus spp.*) or American tea plant are locally abundant. Broomsedge (*Andropogon spp.*) is a very common herb in almost every community. Other herbs frequently encountered are violets (*Viola spp.*), potentilla, beggar's tick, pussy's toes (*Antennaria spp.*), golden aster, tickseed, and lespedeza. A typical upland disturbed community that has not been cultivated is illustrated in figure 4.

PINE

All of the pine stands occurring on the reservation are heavily dominated by either short leaf pine or loblolly pine (*Pinus taeda*), but never by a mixture of the two. With the exception of one of the loblolly pine stands sampled, all of the mature stands have been destroyed by lumbering. The immature stand is very dense, ranging from 350 to 600 trees per acre with the average tree being about

TABLE II.
DATA ON AN UPLAND DISTURBED AREA

Species	Rel. Freq.	Rel. Den.	Trees/ Acre
Short leaf pine	60	48.9	51.2
Pignut hickory	15	3.7	4
Blackjack oak	32.5	10	10.7
Southern red oak	52.8	21.9	23.4
Post oak	25	8.8	9.4
Black oak	5	1.2	1.3
Scarlet oak	12.5	3.7	4
White oak	10	2.5	2.7

TABLE III.
DATE FOR FOUR STANDS OF PINE, TWO DOMINATED BY SHORT LEAF PINE AND TWO BY LOBLOLLY PINE

Species	Rel. Freq.	Rel. Den.	Trees/ Acre	Rel. Dom.	B.A./ Acre
Stand I (Short leaf pine)					
Short leaf pine	100	95	558.5	97.7	97.6
Loblolly pine	5	1.3	7.6	.4	.4
Scrub pine	5	1.3	7.6	.6	.6
Black oak	5	2.5	14.7	1.2	1.2
Stand II (Short leaf pine)					
Short leaf pine	95	84	308.5	84.3	68.7
Loblolly pine	25	14	14.7	14.7	11.9
Scrub pine	5	1	3.7	.4	.3
Southern red oak	5	1	3.7	.5	.4
Stand III (Loblolly pine)					
Loblolly pine	100	100	410.6	100	153.4
Stand IV (Loblolly pine)					
Loblolly pine	90	71	347.9	74.6	51.1
Short leaf pine	40	20	97.9	18.3	12.6
Scrub pine	10	4	15.6	1.2	1.2
Hawthorn	10	2	9.8	.7	.5
Dogwood	5	1	4.9	1.2	.8
Mockernut hickory	5	1	4.9	1.4	1
Sweet gum	5	1	4.9	1.4	1

five inches DBH. Table III illustrates the importance of the dominant species in these stands. Bar graphs illustrating the relative frequency, density, and dominance of the species in these four stands are given in figure 6. Short leaf pine is found in all areas of the reservation while loblolly pine is usually restricted to the habitats that have occurred as a result of man's activities.

There is no understory as such, but individuals of dogwood, hawthorn (*Crataegus*), oak, and hickory occur scattered through the stand. There is no shrub layer and practically no herb layers. Broom

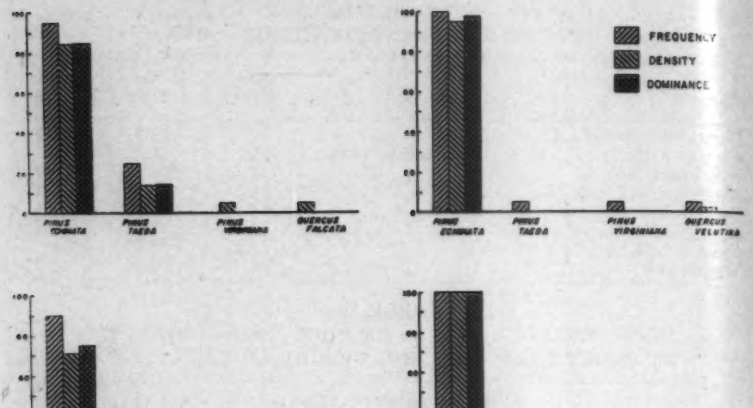

FIGURE 6. *Bar graphs illustrating the relative frequency, density, and dominance of species in four pine stands. Note that the stands are dominated either by loblolly pine or short leaf pine, but not by both.*

sedge is common as is bracken fern (*Pteridium aquilinum*) where burning has occurred. The pine community represents about five percent of the area.

FLOOD PLAIN

River birch (*Betula nigra*) with an average relative dominance of 55.5 percent dominates the flood plain. Other important species and their relative densities are tulip popular (*Liriodendron tulipifera*) 13.1, and short leaf pine 7.5 percent (Table IV). The area occupied by flood plain is overemphasized in figure 1 since part of the shaded area represents the rivers and streams themselves. Much of the bottom land has been cultivated and is reverting to forest.

The most frequent members of the understory are sourwood, river birch saplings, sassafras, and alder (*Alnus rugosa*). Blackberries (*Rubus spp.*) are the most common shrubs while common vines are honeysuckle and species of greenbriar. Often the lower layers are replaced by a dense tangle of cane (*Arundinaria*) and greenbriar. In extreme situations like steep banks and north facing rocky slopes, species of rhododendron, viburnum (*Viburnum*), laurel (*Kalmia*), dog hobble (*Leucothoe*), and buttonbush (*Cephalanthus*) may be abundant. No herbs are common to all flood plain communities, but locally, sedges and species of thoroughwort (*Eupatorium*) and buttonweed (*Diodia*) are abundant.

TABLE IV.
DATA ON TWO FLOOD PLAIN COMMUNITIES

Species	Rel. Freq.	Rel. Den.	Trees/ Acre	Rel. Dom.	B.A./ Acre
Stand I					
River birch	82.5	46.7	124.2	56.9	63.7
Sycamore	17.5	5.6	14.9	5.7	7.5
Tulip poplar	45	16.8	44.7	10.3	11.6
Short leaf pine	25	10	26.6	6.6	7.4
Black gum	5	1.2	3.2	.9	.9
Sweet gum	7.5	2.5	13.8	1.7	1.9
Red maple	10	2.5	13.8	1.5	1.8
Mockernut hickory	2.5	.6	1.6	2	2.2
Persimmon	10	2.5	13.8	1.9	2
Black walnut	5	1.2	3.2	.3	3.4
Southern red oak	2.5	.6	1.6	.3	3.4
Hophornbeam	5	1.2	3.2	.3	3.4
American basswood	2.5	.6	1.6	.3	3.4
White oak	10	3.7	9.8	5.8	7.6
Serviceberry	7.5	1.9	5	1.2	1.3
American beech	5	1.2	3.2	3.7	4.2
Hornbeam	2.5	.6	1.6	.1	.1
Stand II					
River birch	90	64.3	174	77.4	77.9
Sycamore	15	3.7	10	3	3
Tulip poplar	15	9.4	25.4	7.5	7.6
Short leaf pine	12.5	5	13.5	3	3
Red maple	7.5	2.5	6.8	.9	.9
Persimmon	2.5	.6	1.6	.6	.6
Black walnut	12.5	6.2	16.7	5	5
American beech	5	1.2	3.2	.4	.4
Sassafras	5	5	13.5	1.6	1.6
Sourwood	2.5	.6	1.6	.2	.2
Black willow	2.5	.6	1.6	.2	.2

DISCUSSION

This area, like similar ones throughout the Piedmont, has a long history of continued disturbance by white inhabitants since about the middle of the last century. Disturbance by fire, either from Indian activity or natural causes, has probably always played an important role in the vegetation of the area.

Disturbance by man has taken two primary courses, one by clearing for cultivation, and the other by lumbering. Clearing of the land for cultivation began about 1832 and continued actively until about the time of the Civil War. Farming was prevalent until almost the end of the century when poor yields due to the lowering fertility of the soil resulted in wholesale abandonment of Piedmont farms which continued on into the early part of the present century. The abandoned farms were invaded by weedy annuals succeeded by perennials, pine stands, and eventually the secondary growth of hardwoods. As the manufacture of paper became more important, man began clearing the pine in these areas for pulpwood. This

selective lumbering of pine was continued until the reservation was purchased by Lockheed Aircraft Corporation, at which time most of the mature pine stands were removed. Recent lumbering in the region differs from earlier activities in that few hardwoods are cut. The pine is removed from those hill tops and other areas where it is economical to establish a temporary mill.

The history of the area as stated above is the key to the present vegetation which can now be discussed in greater detail. Oak-hickory-pine is the upland climax community, occupying about 80 percent of the area. The composition of this community is influenced by topography ranging from a situation of mixed oak with less than 10 percent pine and hickory on the north slope, to a combination in which hickory and pine represent 44.4 percent of the relative density on the south slope. Some of the species of oak also show correlation with topography, notably scarlet oak and chestnut oak on the north slopes and in the valleys, and southern red oak on the hill tops and south slopes. In the natural state it is probable that pine plays a more important role than is evident from the sampling, since a great deal of pine has been selectively removed from this type of community on the hill tops and flat areas.

Pine stands are pure short leaf or loblolly pine with only a small amount of mixing. The ubiquitous nature of short leaf pine as opposed to that of loblolly pine which occurs almost exclusively in disturbed areas, suggests that short leaf pine may be the native pine in this area. Loblolly pine is either planted or is dependent upon cultivated fields for establishment. Scrub pine (*Pinus virginiana*) is relatively rare and its habitat is unpredictable, while white pine (*Pinus strobus*) is restricted to steep north slopes. Although white pine competes with many deciduous species in these sites, it appears to be maintaining itself, and is of special interest since it is at the limit of its southern distribution.

The disturbed areas are developing into climax communities, whether or not they have been cultivated. Fields that supported commercial crops less than five years ago are now dominated by weedy herbs, and pine seedlings are already abundant in many areas. Some of the fields in moist areas along the river bottom are being invaded by alder, as intermediate in the development into flood plain communities. Where upland areas have not been cultivated, the climax species are beginning reproduction without going through the herbaceous stages. Such communities contain equally important amounts of oak and pine, but hickory seedlings are seldom encountered.

Since the rivers in the reservation are still actively downcutting, and the processes of soil genesis are very slow, it is probable that the flood plain communities will remain essentially as they are for some time. At present, these mature flood plain stands are heavily dominated by river birch which is freely reproducing itself and is well represented in all size classes. As the streams wind through the abrupt hills, there are many places where there is no true flood

plain. Steep rocky slopes descend all the way to the river's edge, and species reminiscent of the mountains to the north are abundant. Genera represented are rhododendron, viburnum, laurel, and dog hobble, while buttonbush frequently occurs near the water's edge at the base of the slopes.

There is naturally a great amount of variation in an area as large as the one studied, but every effort was made to sample stands that are representative of the entire area. Although more extensive sampling would undoubtedly reveal variations in the composition of the overstories as presented here, it does not seem likely on the basis of observations that these figures would vary to a large extent. The fact that the data presented here are in general agreement with other studies in the Piedmont also suggests that the overstory data presented are probably representative of the area as a whole. Braun (1950) calls the major forest community of the Piedmont oak-pine. She indicates, however, that pine is an important, but secondary, constituent of the community, and that hickory is not of sufficient importance to be named as one of the dominants. Although hickory has been placed in the title of this community in the reservation, it should be mentioned that this is probably a local situation and does not apply to the southern Appalachians that Braun is attempting to describe. Oosting (1942) presents data that are similar to this study for oak and hickory. In the North Carolina Piedmont which he studied, pine seems to be less important in the overstory of the climax community. North Carolina is on the Atlantic drainage system of the Piedmont while the area studied here is on the Gulf of Mexico drainage system, and Nelson (1956) reports that pine is more important on the west side of the Atlantic-Gulf divide than on the east side of it.

The future of the area depends upon the amount of protection that it receives. There will probably be very little disturbance except for a small area around the reactor. This will permit the reservation to revert to a climax community that may be about 40 percent pine-hardwood, 40 percent pure hardwood, and 15 percent pine as it was in the past (Nelson, 1956). On the other hand, fire has always been a factor that has opened areas in the climax forests of the Piedmont, and it may be that the presence of pine is dependent upon such disturbance. In areas where mesophytic conditions exist, deciduous species replace pine, and the absence of fire may permit the establishment of conditions favorable for hardwood dominance. A minimum of about 150 to 200 years may be required before such climax conditions are reached.

LITERATURE CITED

Bard, Gily E. 1952 Secondary Succession on the Piedmont of New Jersey. Ecol. Monog., 22: 195-215.

Braun, E. Lucy 1950 Deciduous Forests of Eastern North America. Blakiston: Philadelphia.

Cottam, Grant, and J. T. Curtis 1956 The Use of Distance Measures in Phytosociological Sampling. Ecology, 37: 451-460.

Fernald, M. L. 1950 Gray's Manual of Botany, Eighth Edition. American Book Co.: New York.

Keever, Catherine 1950 Causes of Succession on Old Fields of the Piedmont, North Carolina. Ecol. Monog., 20: 229-250.

Nelson, T. C. 1956 The Present Extent and Distribution of Hardwood Forest Types in the Piedmont. Bull. Ga. Acad. Sci., 14: 31-32. (Abs.)

Oosting, Henry J. 1942. An Ecological Analysis of the Plant Communities of Piedmont, North Carolina. Amer. Mid. Nat., 28: 1-126.

Platt, Robert B. and Joseph A. Mohrbacher 1959. Studies in Radiation Ecology. I. The Program of Study. Jour. Ga. Acad. of Sci. 17:1-30.

Quarterman, Elsie, 1957 Early Plant Succession on Abandoned Cropland in the Central Basin of Tennessee. Ecology 38: 300-309.